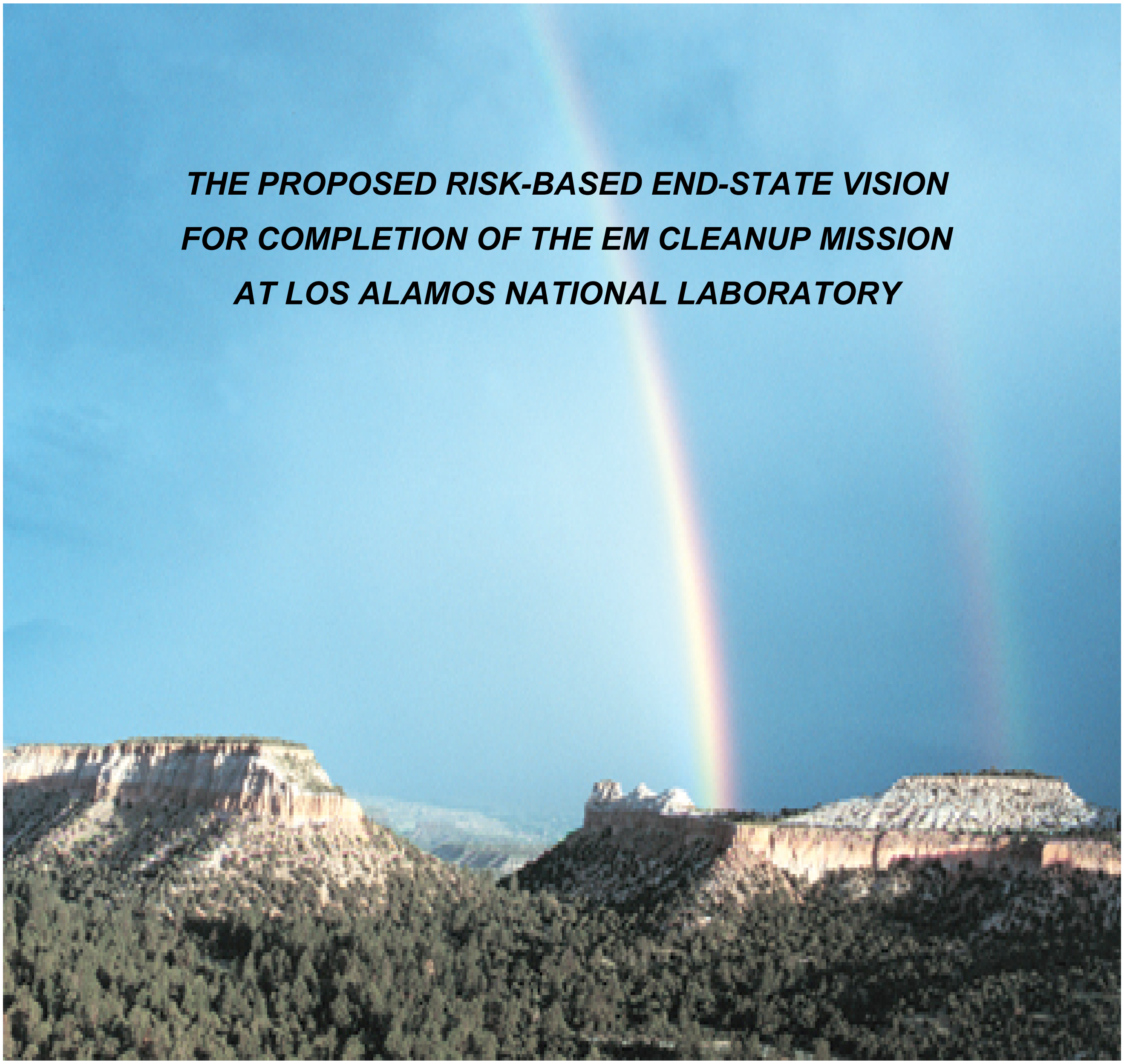
Pre-decisional Draft

November 3, 2003



THE PROPOSED RISK-BASED END-STATE VISION FOR COMPLETION OF THE EM CLEANUP MISSION AT LOS ALAMOS NATIONAL LABORATORY

Remediation Program
RRES

LA-UR-03-8254

1943 - 2003
Los Alamos
NATIONAL LABORATORY
Ideas That Change the World

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1 INTRODUCTION

This document describes the proposed site-wide goal for environmental remediation at the Los Alamos National Laboratory (LANL). The proposed goal is described as a "vision" of how the LANL campus will look when the Department of Energy (DOE) Environmental Management (EM) program cleanup mission is complete and the National Nuclear Security Administration (NNSA) assumes full responsibility for environmental management at LANL. The vision juxtaposes land-use, program, and facility plans with remediation requirements, establishing a conceptual completion goal (or end state) that is both realistic and protective. The purpose of the vision is to identify where and how potentially harmful exposures to hazardous contaminants might occur under projected future conditions, and to determine what actions will be necessary and sufficient to minimize the potential for harm under those condition. Consistent with the objectives of cleanup, the vision conceptualizes specific end-state conditions that will minimize the potential for harm in the future. Because this paradigm is consistent with the federal government's definition of risk as the probability that a substance or situation will produce harm under specified conditions, the vision is referred to as a *risk-based end state*.

The April 2003 DOE Policy 455, *Use of Risk-Based End States*, requires DOE EM sites to define and document a risk-based end-state vision that is acceptable to regulators and stakeholders, and then to revise cleanup program plans as necessary to achieve that end-state in the most efficient manner (ref DOE Policy 455.1). The policy is a formal mandate for EM sites to implement risk-based corrective action programs as described in numerous DOE, Environmental Protection Agency (EPA) publications, ASTM Standard Guides, and National Research Council recommendations (refs including DOE Expedited Site Characterization and SAFER).

Risk-based corrective action is an application of standard scientific, engineering, and mathematical principles, enabling steady progress in solving even very complex cleanup problems. The complexities of cleanup at a typical EM site are generally similar: Multiple contaminants distributed in multiple environmental media, released over long periods of time and large areas of land. Uncertainties in source(s), nature, extent, transport, and fate of contaminants are very large and can never be absolutely eliminated. Risk-based corrective action provides an objective means of managing uncertainties to the degree necessary and sufficient to make defensible decisions about effective cleanup actions.

Risk-based corrective action is a defining element of LANL's integrated technical strategy, which was formally submitted to the New Mexico Environment Department (NMED) in 2000 as Revision 8 of the LANL *Installation Work Plan* (ref). The LANL technical strategy also incorporates guidance developed by EPA Region VI, which maximizes the benefits of risk-based planning by applying it first on a site-wide scale to rank and prioritize among multiple corrective action sites, then on a site-specific scale to optimize the corrective actions to achieve cleanup goals for sites both individually and collectively (ref EPA R6 CAS).

The risk-based end-state vision describes cleanup goals that would be protective under the planned future uses described in two planning documents. The first is LANL's *Ten-Year Comprehensive Site Plan*, which describes NNSA's facility and operations over a 10-year planning window; the second is *Land Transfer Report to Congress under Public Law 105-119, A Preliminary Identification of Parcels of Land in Los Alamos, New Mexico for Conveyance or Transfer*, which identifies specific parcels of land that are planned for transfer from DOE ownership. In addition, the future end-state vision makes use of other LANL documents, including those that forecast the environmental impacts of planned activities, in compliance with the National Environmental Policy Act.

The DOE's risk-based end-state initiative is fully consistent with the EPA's recent endorsement of "systematic planning," which uses risk-based decision methods to ensure objectivity, defensibility, and cost-effectiveness in corrective action programs. (ref TRIAD) "Systematic planning is the scaffold around which defensible site decisions are constructed… First and foremost, planning requires that key decision-makers collaborate with stakeholders to resolve clear goals for a project." LANL will collaborate with its stakeholders to revise the proposed risk-based end-state vision as needed to define clear goals for completion of its EM-sponsored cleanup work. Once the final end-state goal is resolved with public and regulatory stakeholders, LANL will use risk-based decision analysis to objectively, defensibly, and cost-effectively align its remediation project plans to achieve that goal.

1.1 Organization of the Report

The format and content of this report strictly adheres to DOE's *Guidance for Developing a Risk-Based, Site-Specific End State Vision*.

The remainder of this section provides background and programmatic context for the descriptive information in Sections 2, 3, and 4. The descriptive information in Sections 2, 3, and 4 focuses on attributes that relate to risk on three spatial scales: Regional, site-wide, and hazard-specific. The attributes of risk are natural and man-made features, events, and processes that impact the potential for harm to living systems from exposures to environmental hazards. Major risk attributes include the type and amount of contamination in environmental; the current distribution and potential migration of contamination in the environment; and the conditions and situations that may result in contact between living organisms and contamination at specific locations. These attributes will change over time, as remediation actions are completed and LANL operations continue amid evolving Federal, Tribal, state, and municipal conditions and constraints.

To differentiate between the present state and the planned end-state, the three spatial descriptions in Sections 2, 3, and 4 depict two time frames, present-day and end-state. As prescribed by the DOE, the end-state vision represents a snapshot of conditions anticipated 20 years after completion of the EM-sponsored cleanup mission. For LANL, the risk-based end-state vision conceptualizes the year 2035, consistent with a planned EM completion in 2015.

Section 2 depicts LANL in its regional context under current and planned conditions. The current conditions reflect factual knowledge in 2003, while the planned conditions reflect objective goals to be achieved through 2035. Section 3 depicts the current and planned conditions at a slightly smaller scale that encompasses the LANL boundary and directly adjacent environs. Finally, Section 4 describes the current- and end-state at the scale of watersheds, within which one or more contaminant sources coexist. The site- and hazard-scale descriptions in Sections 3 and 4, respectively, are both graphical and narrative.

1.2 Site Mission

Since World War II, scientific research and technology development have been conducted at the Los Alamos National Laboratory in support of national security. That mission endures today: To develop and apply science and technology to

- Ensure the safety and reliability of the U.S. nuclear deterrent.
- Reduce the threat of weapons of mass destruction, proliferation, and terrorism.
- Solve national problems in defense, energy, environment, and infrastructure.

The concepts of risk and the constructs of risk management are fundamental to the accomplishment of every element of the LANL mission.

1.2.1 Management of National Security Risks

Under the current structure of the federal government, the National Nuclear Security Administration (NNSA) sponsors the core national security mission work conducted at LANL. It is expected that LANL will remain a center of research and development in support of national security into the foreseeable future.

The goal of the national security mission is to develop countermeasures to threats posed by weapons and tactics of modern warfare and terrorism. These countermeasures include surveillance and monitoring of existing and emerging weapons and tactics and developing and maintaining a deterrent arsenal. The development of technologies to understand threats and develop deterrents and countermeasures requires a significant level of research in nearly every branch and specialty of science, from the most fundamental to the most esoteric. The general technical capabilities required by the LANL mission are:

- Atomic-to-global scale sensor and detector research and development to acquire information about threats.
- Data storage technologies, data display capabilities, and computational methods to assemble and interpret an ever-growing body of information.

- Research, engineering, fabrication, storage, testing, treatment, and disposal of chemical, biological, and radiological materials.

1.2.2 Management of Operational Risks

The achievement of the LANL mission requires the use and disposal of radioactive materials, chemicals, and pathogens. As evidenced by their use in terrorism and warfare, these substances are harmful under specific conditions. Their use and disposal at LANL is carefully controlled at every stage through safe operating procedures developed to prevent known conditions of harm. These procedures reflect federal laws, state and federal regulations, and DOE directives. Safe operating procedures limit the doses, exposure frequencies, and exposure durations to protect workers. The limits are typically 10- to 1000-times lower than thresholds known to cause harm.

Since 1996, all LANL operations have been performed within an integrated safety and security management system, which ensures that associated hazards are identified and procedures are developed to mitigate the risks from hazards as a routine part of the work authorization process. Elements of the integrated safety and security management system include radiation protection of workers, non-nuclear authorization basis, and management of nuclear facilities.

The risks associated with operations involving radioactive materials are controlled primarily through procedures that implement the requirements of DOE Orders. These Orders reflect the state of knowledge about radiological doses as defined, refined, and maintained by national and international scientific organizations. (ref NCRP, ICRP, IAEA, etc.) Procedures are followed through every phase of LANL operations involving radioactive materials to prevent against harmful conditions of exposure. These procedures are implemented to protect both LANL workers and other members of the public.

Analogous procedures are followed to manage the risks associated with toxic chemicals. These procedures comply with standards and regulations administered primarily through the Occupational Safety and Health Administration (OSHA) and the EPA. These regulations and implementing procedures reflect the state of scientific knowledge about the toxicity of various chemicals, and the preventive measures that will ensure against harmful exposures.

Different regulations and policies apply to ensure against harmful exposures under different conditions, including individual work-spaces to facility effluent stacks. In general, compliance with OSHA regulations prevents workers from being exposed to harmful amounts of toxic chemicals, and compliance with EPA regulations and DOE Orders likewise protects other members of the public.

1.2.3 Management of Environmental Risks

There are several facilities and operations at LANL that release radioactive and chemical substances into the environment. All releases are monitored, reported, and audited in accordance applicable laws, regulations, and requirements. Monitoring ensures that releases of potentially harmful substances are below amounts that are known to cause harm under potential conditions of exposure in the environment.

Liquid and air-borne releases are monitored at the point of discharge, and at locations either down-stream or down-wind from the discharge. The monitoring results are reported to the EPA, NMED and/or the DOE to independently validate compliance with applicable regulations. Environmental risks from LANL operations are managed in accordance with the following primary requirements:

- DOE Order 435.1 *Radioactive Waste Management* (formerly DOE Order 5820.2A): Addresses risk of radioactive waste disposals sites.
- DOE Order 450.1 *Environmental Protection Program* (formerly DOE Order 5400.5): Addresses risk from radioactivity released into the environment from all sites and facilities, through the post-closure period.
- RCRA Hazardous Waste Facility Permit

The National Environmental Policy Act requires that LANL analyze and report potential environmental risks associated with planned facilities and operations prior to initiating work. Together, these directives ensure that LANL is complying with environmental protection laws, including but not limited to:

- Clean Air Act

- New Mexico Air Quality Control Act
- Clean Water Act
- Safe Drinking Water Act
- Toxic Substances Control Act
- Hazardous and Solid Waste Act
- Resource Conservation and Recovery Act

Operations using toxic substances at LANL were conducted for many years before laws were enacted to prevent unintentional harm to people and the environment. Still, LANL began sampling studies and voluntary cleanups in 1946, after the successful completion of their initial mission. These efforts continued through the 1960s. Throughout the 1970s, LANL implemented more formal practices to identify and assess contamination in the environment. In the 1980s, a program was funded by DOE EM to conduct corrective actions at LANL sites where contamination was found to present a potential risk to human health and the environment. The specific requirements for corrective actions for radiological contamination in the environment are found in DOE Order 5820.2A (superseded by DOE Order 435.1), which incorporates by reference corrective actions under the RCRA for hazardous chemical contamination in the environment. The goals of the LANL environmental cleanup program are to

- protect human health and the environment from exposure to hazardous chemical or radioactive materials resulting from past treatment, storage and disposal practices, and
- meet or exceed the environmental cleanup requirements of the LANL RCRA permit to operate hazardous waste facilities.

1.3 Status of Cleanup Program

The EM mission at LANL was initiated in 1989 and is scheduled to be complete in 2015 on the basis of its 2003 performance management plan (ref). In its initial RCRA facilities assessment, LANL identified over 2,000 individual “potential release sites” across its 43-square-mile area that would be further evaluated through its EM-sponsored remediation program. Potential release sites include such things as septic tanks and associated drain lines, chemical storage areas, wastewater discharge areas, material disposal areas, high-explosive firing sites, storage tanks, and spills. Potential release sites are located on mesa tops, canyon walls, and canyon bottoms. No two are exactly alike, varying in terms of contaminant type (or “nature,” such as chemical solvents, radioactive substances, and explosives), distribution (or “extent,” either localized or broadly distributed), mobility (or “transport,” in air or water), and transformation (or “fate,” such as radioactive decay or biodegradation).

In 1999, LANL updated its remediation approach from one focused on individual sites and their potential to impact human health to one focused on aggregates of sites and their cumulative potential to impact human health and/or the broader ecosystem. The revised approach is documented in the facility-wide *Installation Work Plan*, which was approved by the NMED in 2002. While the corrective-action Order issued to DOE and LANL by NMED is pending, LANL intends that its EM-sponsored cleanup activities will be completed in accordance with the risk-based process described in the approved work plan. The following subsections describe the key elements of the LANL cleanup program.

1.3.1 General Technical Strategy and Cleanup Goals

Although not an official pilot site, LANL is following the technical framework endorsed by EPA Region VI in its *Corrective Action Strategy Guidance for Pilot Projects* (ref).[1] EPA Region VI developed its risk-based corrective action strategy to accelerate corrective action at RCRA sites, a goal that is consistent with DOE’s risk-based end-states policy. Moreover, the EPA Region VI corrective action strategy begins with the clarification of a final risk goal, which, like DOE’s risk-based end-state vision, is the level of

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[1] The EPA Region VI corrective action strategy addresses the primary basis of the NMED order, which is reducing risk to human health and the environment. What is more, the Region VI strategy requires the early determination of performance standards as an objective basis of EM completion, which would remedy one of the primary objections to the order, namely the lack of completion criteria.

protection to be achieved and maintained by the facility based on future land use, real receptors, and known releases.

The final risk goal is one of three categories of performance standards recommended by Region VI, the other two being source control and applicable statutes and regulations. Table 1.3-1 lists Region VI's descriptions of, and LANL's proposals for meeting, performance standards.

Table 1.3-1
Proposed performance standards comprising the risk-based end state to be achieved at EM completion

Performance Standard	EPA Region VI Definition	LANL Proposal
Source Control	Control of materials that include or contain hazardous wastes or hazardous constituents, that act as a reservoir for migration of contamination to soil, sediment, ground water, surface water, or air, or as a source for direct exposure. Contaminated ground water plumes are not generally considered a source material.	Eliminating, reducing or stabilizing primary sources (e.g., storage tanks, outfalls, MDAs) Eliminating, reducing or stabilizing secondary sources (e.g., contaminated soils, sediments, alluvial water)
Statutory/ Regulatory	Media-specific contaminant levels that must be achieved, such as maximum contaminant levels (MCLs) in drinking water. These requirements may be specified in Federal, state, and local laws and regulations.	Achieving MCLs and DCGs within water supply system by achieving site- and source-specific ACLs at designated monitoring wells
Final Risk Goal	The level of protection to be achieved and maintained by the facility based on land use and acceptable risk at specific locations and times	Providing 95% confidence that the probability of exceeding applicable thresholds is not greater than 10^{-5} for a period of 20 years under exposures consistent with future land use

Performance standards provide an objective basis for determining the priority of corrective actions and optimizing remedies according to their ability to achieve and maintain the standards. By focusing on known and realistic goals, the Region VI corrective-action strategy emphasizes progress over process. In completing its EM mission, LANL will achieve a risk-based end state vision that integrates Region VI performance standards to protect both human receptors and the environment from all sources of contamination across the entire LANL campus. To accomplish this, LANL has developed a systematic risk-based decision analysis process.

Risk-based decision analysis provides many benefits:

- Facilitates prioritization of contaminated sites at individual installations.
- Provides a consistent mechanism for addressing both simple low-risk sites and complex high-risk sites, establishing a systematic approach for sites of differing complexity.
- Guides data collection to support the development of site-specific cleanup goals, ensuring that data collected are demonstrably linked to ensuring protection of human health and the environment.
- Assesses cumulative risks from all sources affecting the same human or ecological receptor, quantifying the overall, facility-wide risk encountered by potential target receptors.
- Encourages early action at sites where the risk is imminent and at sites where the risk is low but remediation is rapid and inexpensive.
- Considers relevant uncertainties explicitly using stochastic modeling approaches, and considers options for reducing relevant uncertainties.
- Integrates the selection of cleanup options with the cleanup goals, evaluating multiple options in a quantitative framework.

- Provides a means of revisiting remedies over the long term through repeated risk evaluations if site conditions change over time.
- Takes place in a public forum, explicitly presenting all relevant science, assumptions, and judgments.
- Undergoes external, public and independent scientific peer review before decisions are implemented.
- Complies with relevant state and federal statutory programs, being flexible enough to incorporate applicable state and EPA regulations.

The risk-assessment methods used to provide input to the decision analysis is itself graded to ensure that the level of technical rigor matches the level of information needed for a particular decision in the cleanup process. LANL follows EPA's *Process for Conducting Probabilistic Risk Assessment* (ref).

1.3.2 Investigation and Assessment Strategy

Investigations and assessments are conducted iteratively to support cleanup decisions that ensure progress toward achieving performance standards. Since the source-control performance standard applies to individual release sites, site-specific investigations are tailored to provide information necessary and sufficient to assess the site-specific practicability of alternative source-control measures. Since the final risk goal applies to all releases collectively, site-wide investigations are tailored to provide information necessary and sufficient to assess the potential for harm from exposures to environmental media that may be directly or indirectly contaminated from one or more release sites. To the extent possible, the site-wide investigations are also designed to provide information necessary and sufficient to assess releases in the context of regulatory performance standards.

1.3.2.1 Source Specific

Before the integrated technical strategy was implemented, site-specific investigations generally followed the traditional RCRA Facilities Investigation approach. Since then, LANL has made substantial progress in streamlining site-specific investigations by identifying feasible site-specific source-control alternatives, and designing investigations to provide information to either confirm or deny the practicability of those alternatives.

According to EPA Region VI, the source-control performance standard applies to "materials that contain hazardous wastes or hazardous constituents, that act as a reservoir for migration of contamination to soil, sediment, ground water, surface water, or air, or as a source for direct exposure." This implies that the source-control performance standard applies to contained or confined hazards (including storage tanks and associated plumbing, landfills, surface impoundments, and evaporation lagoons), but does not apply to media contaminated indirectly as a result of these sources (including air, surface soil, sediment, surface water, groundwater, and biota). Therefore, investigations and assessments designed to support source-control decisions are limited to sites that meet EPA Region VI's applicability criteria.

For sources including septic tanks, shallow-subsurface landfills, surface impoundments and evaporation lagoons, LANL plans to achieve source control by excavation, offsite disposal, and remediation. Accordingly, site-specific investigations are designed to support excavation, waste disposition, and site remediation decisions. These investigations are often based on the results of contaminant transport models developed and implemented to assess the likely nature and extent of contaminated media.

For the majority of the deeper subsurface material disposal areas (MDAs), excavation is dangerous and/or impracticable, and off-site disposal is unlikely or virtually impossible due to the large volumes of deeply buried heterogeneous materials contaminated with a variety of constituents. Source control at MDAs is limited primarily to stabilization of existing caps. To streamline MDA investigations to support stabilization decisions, LANL developed a risk-based characterization process (ref MDA Core Document submitted to NMED).

To design investigations for MDAs, baseline quantitative risk assessments are conducted to evaluate the stability of MDA sources assuming no enhancement of the existing caps. Stability is judged in the context of applicable regulatory standards, including the Safe Drinking Water Act. To further streamline characterization process, models developed for the performance assessment and composite analysis for LANL's operating on-site radioactive waste disposal facility have been modified to account for release and transport of both hazardous and radioactive constituents. (ref PA/CA and TA-54 RFI Report) (Note that the "inadvertent site intruder" exposure scenario included in the PA/CA is excluded from the risk assessment applications.)

Probabilistic (EPA's "Tier 3") methods are implemented because they provide an efficient but rigorous way to 1) simulate the performance of multiple MDAs within a single numerical framework, 2) determine what modeled characteristics of a given MDA are most important in terms of source stability, 3) evaluate alternative stabilization methods, 4) design appropriate monitoring programs.

(Sections 3 and 4 provide additional detail on baseline risk assessments and risk-based remedy selection for MDAs.)

1.3.2.2 Site-Wide

For contaminated media to which the source-control performance measure does not directly apply, LANL's investigations are designed to provide information needed to evaluate the need for actions to meet media-specific regulatory standards and site-wide risk goals. A quantitative risk-based decision-analysis process is especially valuable for these investigations, since contamination resulting from operations as far back as 1943 has had time to migrate within and between environmental media, resulting in broad spatial distributions and cross-media contamination.

Baseline risk assessments are conducted to understand the impacts of contaminants in environmental media, where impacts are evaluated in the context of applicable regulatory performance standards and cumulative risk. To the extent possible, risk assessments are designed to incorporate media-specific standards. Contaminant transport is simulated at scales that account for physical features and processes that may cause multiple contaminants to be transported in air or water to a single point, resulting in coincident exposures. Exposures are modeled consistent with current and reasonably foreseeable land use.

There are eight major watersheds that traverse the 43 square mile LANL campus. These watersheds play a significant role investigations and assessments conducted to support decisions related to the attainment of regulatory performance standards and site-wide risk goal. All of the watersheds are impacted to some extent by contaminants associated with current and/or historic LANL operations. Some of the watersheds are directly impacted by contaminated liquid effluents, and most were indirectly impacted by contaminants carried from other locations into watersheds, primarily in runoff of rainwater and snowmelt. Contamination deposited in canyon sediments are then subject to further transport by perennial and ephemeral stream-flow, and also by winds that are dramatically channeled within some of the steeper, deeper canyons. To account for these physical attributes and processes related to contaminant transport, baseline risk assessments are conducted for each watershed to inform decisions related to the attainment of applicable regulatory performance standards for surface water and air, as well as the final risk goal.

The watersheds also play a major role in assessing groundwater impacts, because the regional aquifer is partially recharged from surface-water infiltration within watersheds. LANL has developed a risk-based decision analysis application to streamline site-wide investigations and assessments for the purposes of achieving applicable drinking-water performance standards and the final risk goal. This systematic decision framework incorporates information collected through geologic, hydrologic, and environmental investigations conducted since the implementation of EM cleanup in 1989, including site-specific characterization studies and regional hydrogeology studies.(ref. Hydrogeologic Work Plan)

Over the last three years, LANL has developed the "infrastructure" needed to implement site-wide groundwater-pathway risk assessment, including:

- A site-wide enterprise GIS for geo-spatial data staging, storage, distribution, analysis and visualization (ref),
- A site-wide three-dimensional hydrogeology data model (ref),
- A site-wide empirical infiltration model (ref),
- A site-wide quasi-three-dimensional vadose zone groundwater flow model (ref), and
- A regional three-dimensional regional-aquifer flow model (ref).

(Section 3 provides detailed descriptions of the site-wide hydrogeology.)

(Sections 3 and 4 provide additional detail on site-wide hydrogeology, and the baseline risk assessment for groundwater.)

1.3.3 Prioritization Strategy

Consistent with the EPA Region VI corrective action strategy, LANL prioritizes work on the basis of risk. An initial prioritization was accomplished by DOE, LANL, and NMED based on semi-quantitative risk attributes, including

- Nature and extent of contamination,
- Potential for on-site exposures, and
- Potential for offsite migration.

Table 1.3-2 lists the watersheds in order of priority as initially determined, along with the compelling rationale for each watershed's rank. This ranking was used to develop the lifecycle baseline for the cleanup project. Specific work elements were planned for each watershed. Annually at the fiscal-year boundary, the baseline is constrained according to the anticipated budget. Work within specific watersheds is aligned to accomplish the greatest progress with the available resources. Consequently, on an annual basis, not all work will be within the highest-priority watershed. The current prioritization listed in Table 1.3-3 may be reconsidered if indicated by the results of the quantitative baseline groundwater pathway risk assessment.

1.3.4 Remedy Selection

LANL has identified likely remedies for cleanup sites. Each remedy will be optimized using risk-based decision analysis to compare the effectiveness of alternative remedy designs at achieving applicable performance standards under the conditions of planned land use.

Table 1.3-2
Initial priority ranking of watersheds as a basis for planning

Watershed Name	Priority	Risk-Based Rationale for Priority Rank
Los Alamos/Pueblo	1	Mobile contaminants; land-transfer parcel; recreational use
Mortandad	2	Mobile contaminants; land transfer; proximity to Pueblo land; recreational use.
Water/ Cañon de Valle	3	Mobile contaminants; and recreational use.
Pajarito	4	Potentially mobile contaminants, and recreational accessibility
Sandia	5	Potential contamination, and recreational accessibility
Ancho	6	Potential contamination, and recreational accessibility
Chaquehui	7	Potential contamination
Frijoles	8	Recreational accessibility

Exposures scenarios have been developed to represent future land use according to existing plans. The vast majority of cleanup sites are on property that is expected to remain under DOE ownership. The risk-based remedy selection decision analysis for these sites will feature industrial-use exposure scenarios for mesa-tops and firing sites, and recreational-use scenarios for canyons. There are 10 parcels of DOE property that were designated for transfer to either Los Alamos County or the Pueblo of San Ildefonso (held in trust by the Department of the Interior). Cleanup goals for these land parcels will be determined using risk-based decision analysis for residential-use scenarios. Finally, LANL plans to release a small section of land to either the National Park Service or the National Forest Service. In either case, contamination on that land will be remediated to levels consistent with a recreational-use scenario. Those levels will be calculated using risk-based decision analysis methods.

1.3.5 EM Completion

For cleanup sites located on DOE property, EM completion will coincide with the attainment of performance standards through remedies approved by the administrative authority. LANL intends for the final risk goal performance standard to meet the intent of the risk-based end state, which represents EM completion.

Long-term performance monitoring and response actions to maintain the risk-based end state will be integrated into the NNSA environmental management system consistent with the requirements of DOE Order 450.1. The location, frequency, and duration of monitoring will be established using systems-engineering design principles, and a logical exit strategy will be defined to ensure that resources are not wasted on unnecessary data collection and reporting.

Table 1.3-3
Planned schedule for task and watershed completion

Planned Completion	Task
FY03	Hydrogeologic characterization well R-02
	Hydrogeologic characterization well R-04
	Hydrogeologic characterization well R-11
FY04	Hydrogeologic characterization well R-03
	Hydrogeologic characterization well R-10
	Hydrogeologic characterization well R-17
FY05	Hydrogeologic characterization well R-27
	Hydrogeologic characterization well R-30
FY06	MDA-H
FY08	MDA-C
FY09	MDA-B
	MDA-T
FY10	MDA-A
	MDA-L
	LA/Pueblo Watershed
	MDA-U
	MDA-V
FY12	Sandia Watershed
	MD-AB
FY13	Frijoles Watershed
FY14	MDA-F
FY15	Mortandad Watershed
	Water/Canon de Valle Watershed
	Pajarito Watershed
	Ancho Watershed
	Chaquehui Watershed
	EM Work Complete by 2015, turnover to NNSA

1.3.6 Long-Term Risk Management

Consistent with the Atomic Energy Act, DOE retains responsibility for radioactive materials used in its programs. This includes responsibility for residual environmental contamination as long as it poses a threat to human health and/or the environment. At LANL, EM sites that cannot be remediated to contaminant levels allowing unrestricted use (either now or in the foreseeable future) will transition to the National Nuclear Security Administration (NNSA). As required by DOE Order 450.1 *Environmental Protection Program*, the Laboratory will explicitly incorporate long-term environmental stewardship activities into an integrated environmental management system supported by NNSA.

What is more, the basic risk-based decision analysis will be used as an adaptive management tool (as described the NAS/NRC in *Environmental Cleanup at Navy Facilities*) for long-term environmental stewardship planning. This approach addresses key issues faced by DOE sites by

- Allowing continuous evaluation, research and development toward innovative solutions to resolve long-term risks (i.e., uncertainties) while convention remedies are implemented to manage short-term risks.
- Periodically reevaluating previous remediation decisions that do not meet LTES goals, even if they are currently protective.
- Integrating public stakeholders in each decision phase.

1.3.7 Public Involvement

The senior managers at LANL have identified community partnerships as one of their top five performance priorities. The risk-based end states initiative and the long-term environmental stewardship initiative will be one of the pilot project for strategic community involvement this fiscal year. LANL's Citizen's Advisory Board and a local anti-nuclear activist organization have already requested copies of this draft document.

2 REGIONAL CONTEXT RISK-BASED END STATE DESCRIPTION

This section is intended to place the LANL site within its larger geographical context. This context establishes the major regional participants in site risk discussions and analysis. The major regional population centers and land surface features are shown in relation to the site. Non-LANL sources of human and ecological risk are shown to establish regional factors to consider when determining overall risk. These features are shown for the current conditions in 2003 and for the risk-based end-state vision date of 2035.

The extent of these maps is quite large. The maps extend south to the northern edge of the city of Albuquerque, more than 40 miles (64 Km) due south from the LANL site, and north to the boundary of the northern most watershed influenced by LANL activity. The eastern extent captures the city of Santa Fe and the foothills of the mountains beyond. The western extent is closest to the LANL boundary because the nearby ridge separating LANL from the rest of the Jemez Mountains serves as the origin for all drainages crossing the LANL site. The maps are not centered on LANL, as the large population centers are present south of the site.

2.1 Physical and Surface Interface

Figures 2.1a and 2.1b show the physical and surface characteristics of the region surrounding the LANL site, including features of administrative, transportation and infrastructure, surface configuration, and hazard areas of concern.

These maps emphasize the remote character of the LANL site. The small towns of Los Alamos and White Rock are the only population centers directly adjacent to the LANL boundary. The maps also show the rugged nature of the local terrain. The many canyons and mesas that compose the LANL site are evident as is the flow pattern created by the Rio Grande, the major river in the region.

The maps also illustrate the complexity of the land ownership patterns in the area. The US Forest Service, US National Park Service, San Ildefonso Pueblo, Santa Clara Pueblo, Cochiti Pueblo, State of New Mexico, US Bureau of Land Management, Valle Grande National Preserve, and Los Alamos County are all major stakeholders in LANL operations.

There are no expected physical surface changes in the time-frame during which EM's mission will be completed and the risk-based end state achieved. Land use at LANL is expected to change to accommodate new facilities, but they are not highly visible at this scale. Land transfers are also expected to change land use and boundaries, and except for a few major transfers, they also do not show as major land ownership changes at this scale.

2.2 Human and Ecological Land Use

Figures 2.2a and 2.2b show the human and ecological land use characteristics of the region surrounding the LANL site, including features showing population centers, land cover / land use, ecological activity, and hazard areas of concern.

The largely undeveloped nature of the area surrounding the LANL site is evident from these maps, with most land used for non-urban activities or protected and managed for natural resources.

Again, no major changes in land use are anticipated near the LANL site in the time frame under consideration. The cities of Santa Fe and Albuquerque are expected to grow, though estimates of this growth are varied and highly dependent on future water supplies in this arid region. The highway corridor between Santa Fe, Espanola, and Los Alamos may experience limited growth, but these roads cross Pueblo land and growth will depend on the goals of the local Pueblo Governments. The road west from LANL crosses National Park Service and Forest Service lands and further development along this route is not expected.

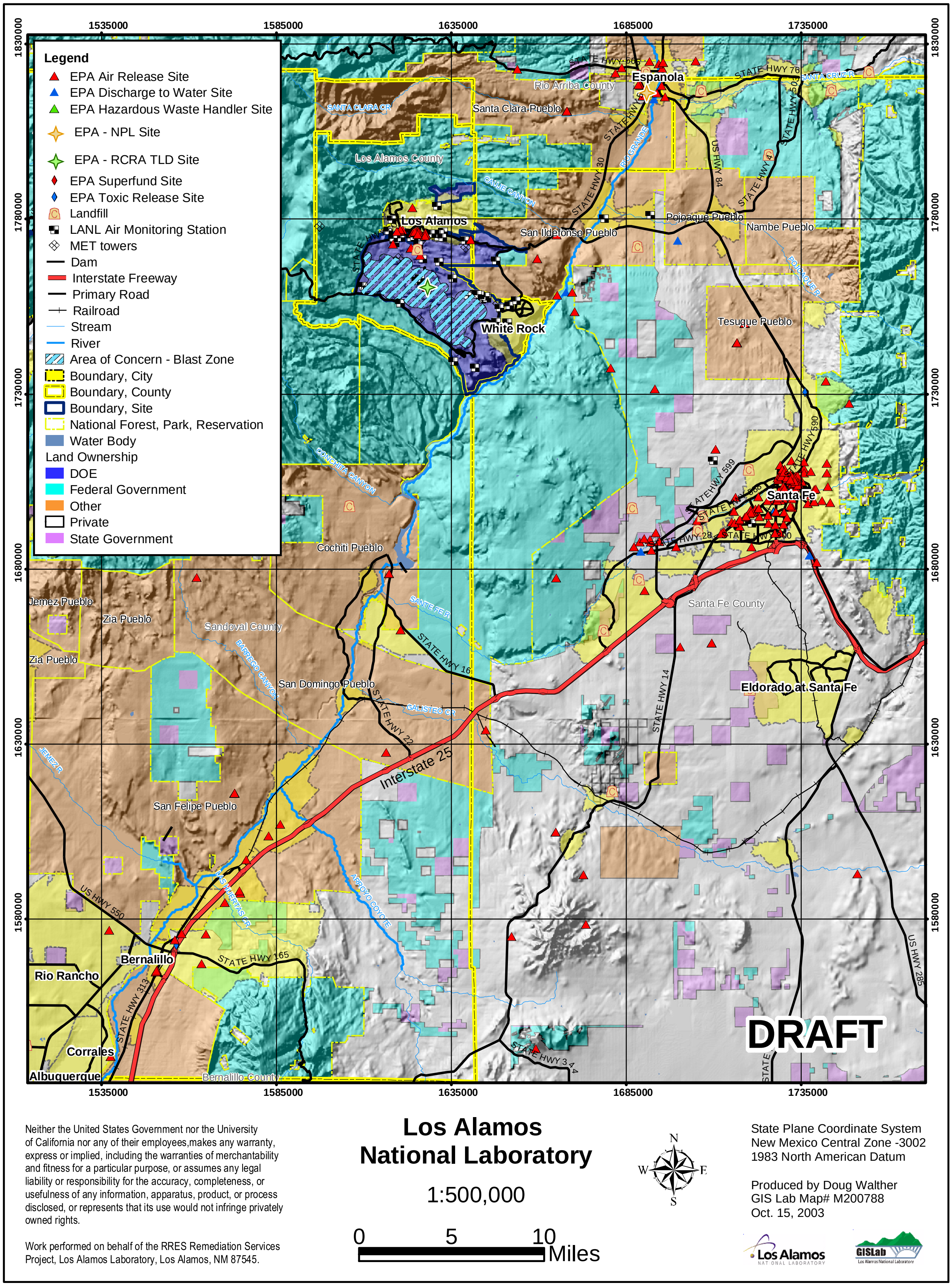


Figure 2.1a. Regional physical and surface interface, Current state.

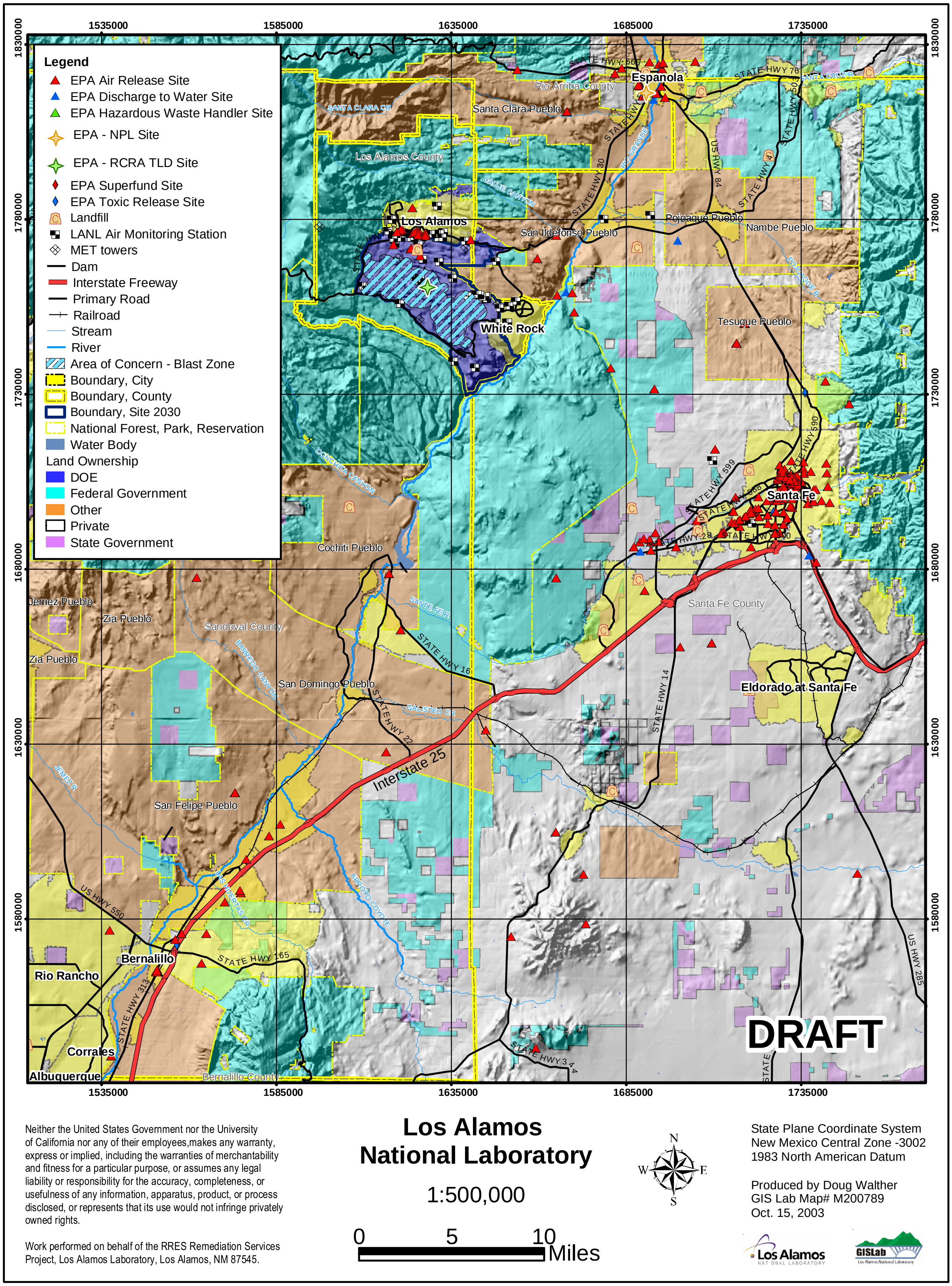


Figure 2.1b. Regional physical and surface interface, End state.

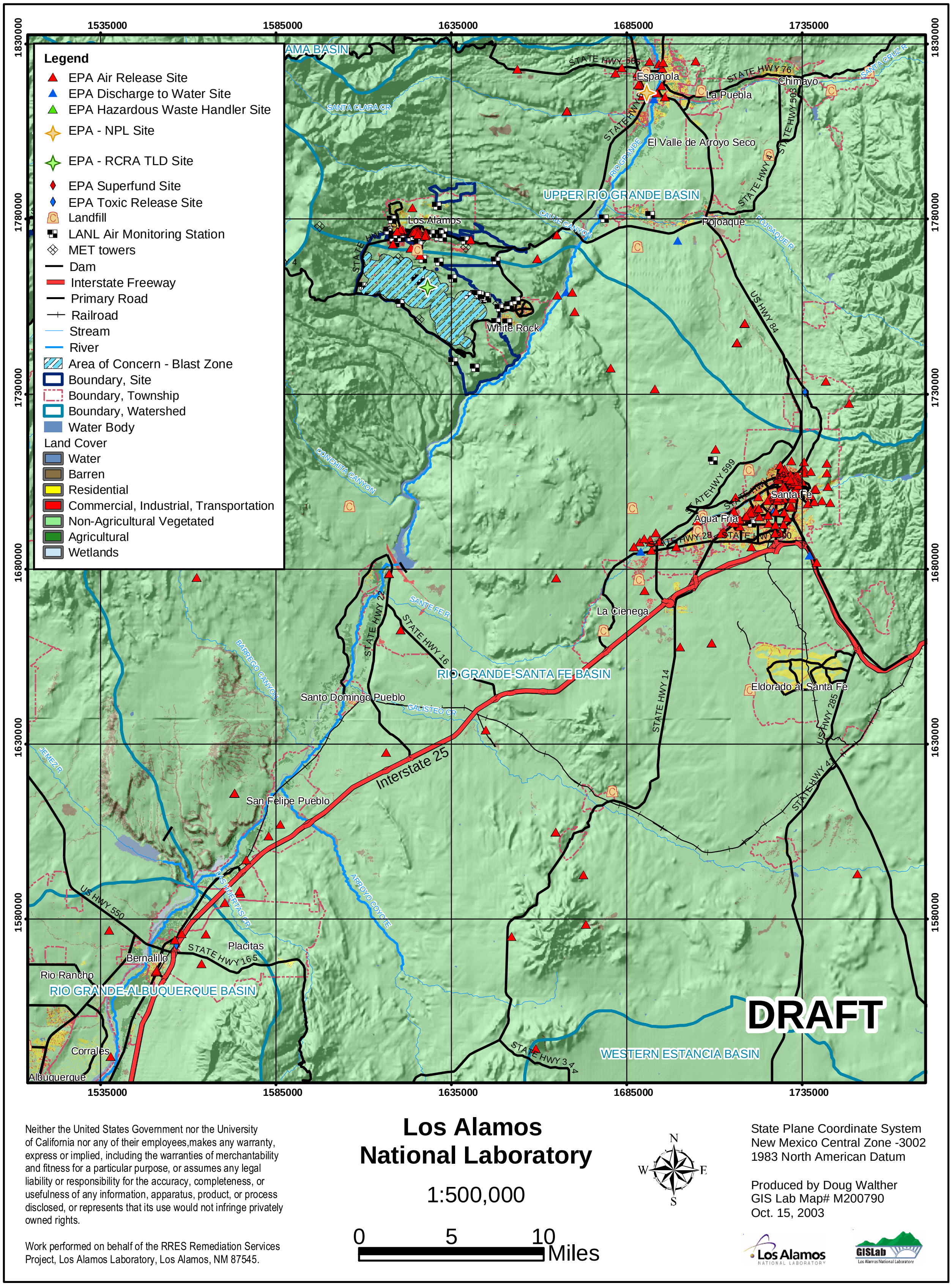
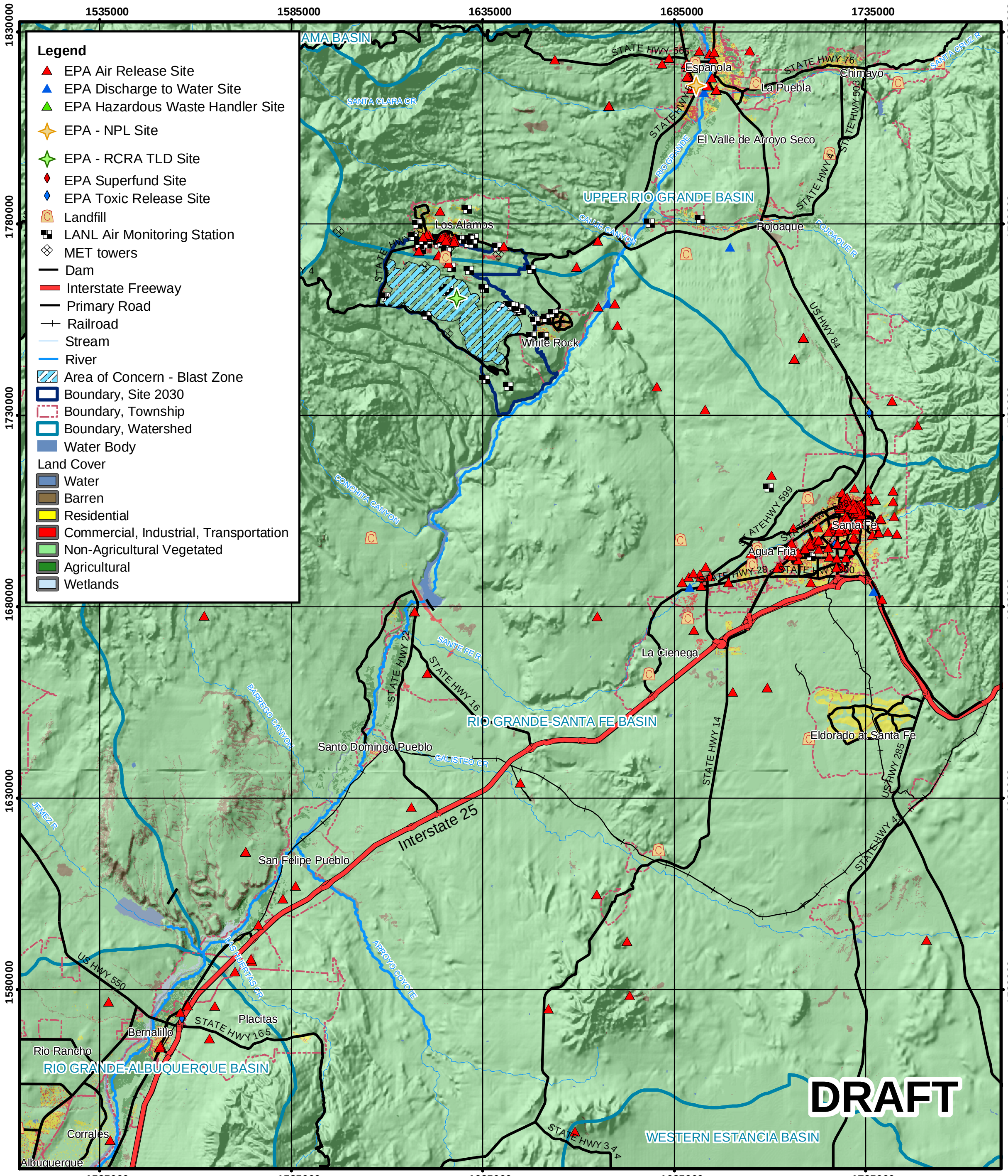


Figure 2.2a. Regional human and ecological land use, Current state.



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Work performed on behalf of the RRES Remediation Services Project, Los Alamos Laboratory, Los Alamos, NM 87545.

Los Alamos National Laboratory

1:500,000

0 5 10 Miles

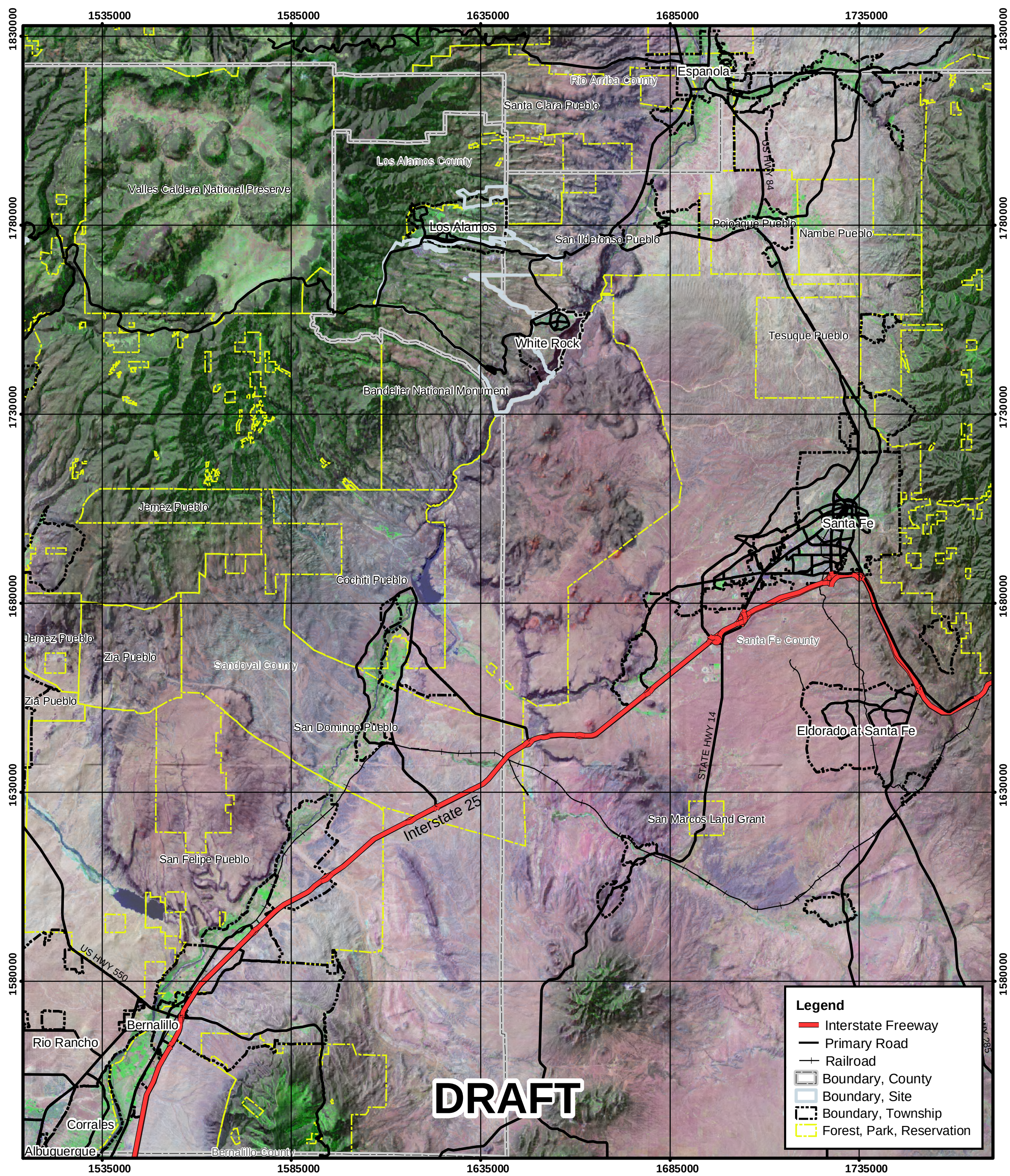
State Plane Coordinate System
New Mexico Central Zone -3002
1983 North American Datum

Produced by Doug Walther
GIS Lab Map# M200791
Oct. 15, 2003

Figure 2.2b. Regional human and ecological land use, End state.

2.3 Satellite Image

To further illustrate the unique nature of the regional topography, a color enhanced LANDSAT image is shown in Figure 2.4 (no custom maps are available at this time for Figure 2.3). The large feature in the northwest of the image is the Valles Caldera, an ancient volcano caldera system that created the Jemez Mountains. The major river, the Rio Grande, and its drainage system are clearly visible. The agricultural activity along the Rio Grande can be seen as well, and the sparse nature of wild vegetation away from the mountain ecosystems is evident. The volcanic origins of the area are clear in the numerous ancient lava flows and structures in the valleys.



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Los Alamos
National Laboratory

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State Plane Coordinate System
New Mexico Central Zone -3002
1983 North American Datum

Produced by Doug Walther
GIS Lab Map# M200853
Oct. 29, 2003

Los Alamos NATIONAL LABORATORY
GISLab Los Alamos National Laboratory

Figure 2.4. Regional landsat photo and surface interface.

3 SITE SPECIFIC RISK-BASED END STATE DESCRIPTION

This section describes the current state of knowledge regarding the attributes of human-health and ecological risks posed by all known radiological and chemical hazards at LANL. These attributes are grouped as follows:

- physical and surface features to provide perspective on the nature and extent of various hazards in relation to natural and cultural features
- cultural and ecological features to identify potential receptors
- land-ownership to understand the potential limits of institutional controls
- demographics to identify potentially exposed populations

3.1 Physical and Surface Interface

As described in the DOE's *Guidance for Developing a Risk-Based, Site-Specific End State Vision*, the attributes of the physical and surface interface fall into the following categories:

- Administrative
- Transportation and Infrastructure
- Surface Configuration, and
- Hazard Areas of Concern

The maps shown as Figures 3.1a and 3.1b depict these attributes as prescribed by the DOE, for the current state (2003) and the planned end state (2035), respectively. The attributes included on both maps are described, followed by a discussion of the differences between the current state and the end state conditions, some of which are not visible on the prescribed map format.

3.1.1 Administrative

DOE includes the following within the category of Administrative:

- Land owned and/or controlled by governmental entities (municipal, state, federal, or tribal)
- Wildlife and wilderness areas, and
- Historic and cultural resources

State and federal government agencies and local Indian tribes control land surrounding Los Alamos County. Of these, three federal agencies (i.e., Bureau of Indian Affairs, U.S. Forest Service, and Bureau of Land Management) control the majority of land in the area. The Santa Fe National Forest comprises 634,486 hectares (1,567,181 acres) of land in several counties. The Española District of the Santa Fe National Forest includes 142,521 hectares (352,170 acres) that border DOE land to the northwest and southeast.

The Bandelier National Monument borders the southwest portion of the Laboratory complex and is managed by the National Park Service. The monument includes 12,950 hectares (32,000 acres) of land, 9,308 hectares (23,000 acres) of which are designated wilderness. All access major routes to the monument's visitor center pass through or along the Laboratory property. Thirteen Native American Pueblos are located within 80 km (53 mi) of the Laboratory. Each tribe has the rights of sovereign government, with technical and administrative assistance from the Bureau of Indian Affairs. The San Ildefonso Pueblo owns a triangular piece of land that directly borders MDA G within Cañada del Buey to the north of the facility. The total area owned by the Pueblo is 10,600 hectares (26,192 acres). In addition to hunting wildlife for food, Pueblo people also harvest the fruit of piñon and juniper trees indigenous to the area. Hunting and gathering activities occur on the land directly adjacent to Mesita del Buey. There are also tribal sacred areas and ceremonial practices that may affect exposures.

3.1.2 Transportation and Infrastructure

DOE includes the following in the category of Transportation and Infrastructure:

- Highways, roads, and railroads;
- Utility transmission lines;

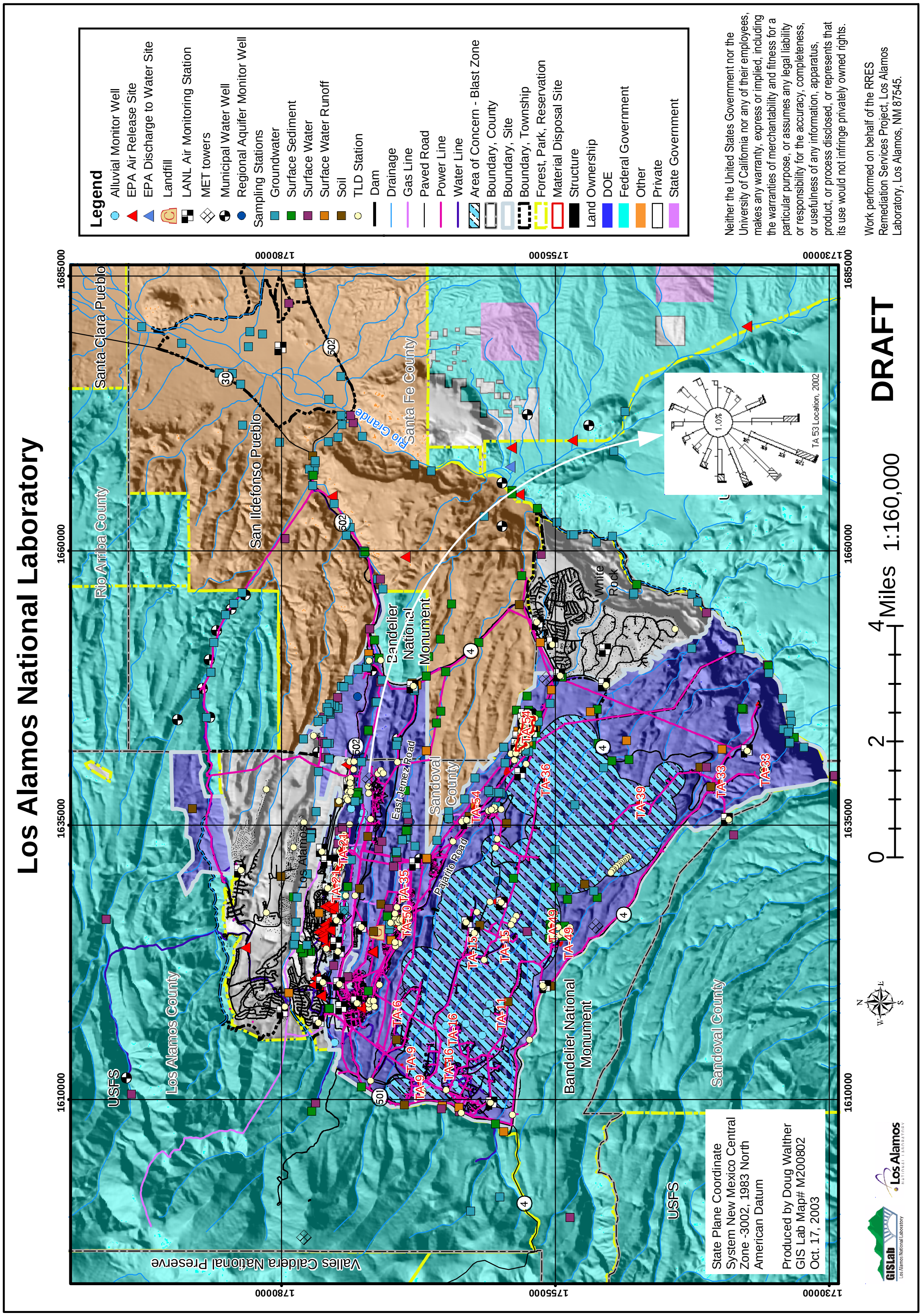


Figure 3.1a. Site physical and surface interface, Current state.

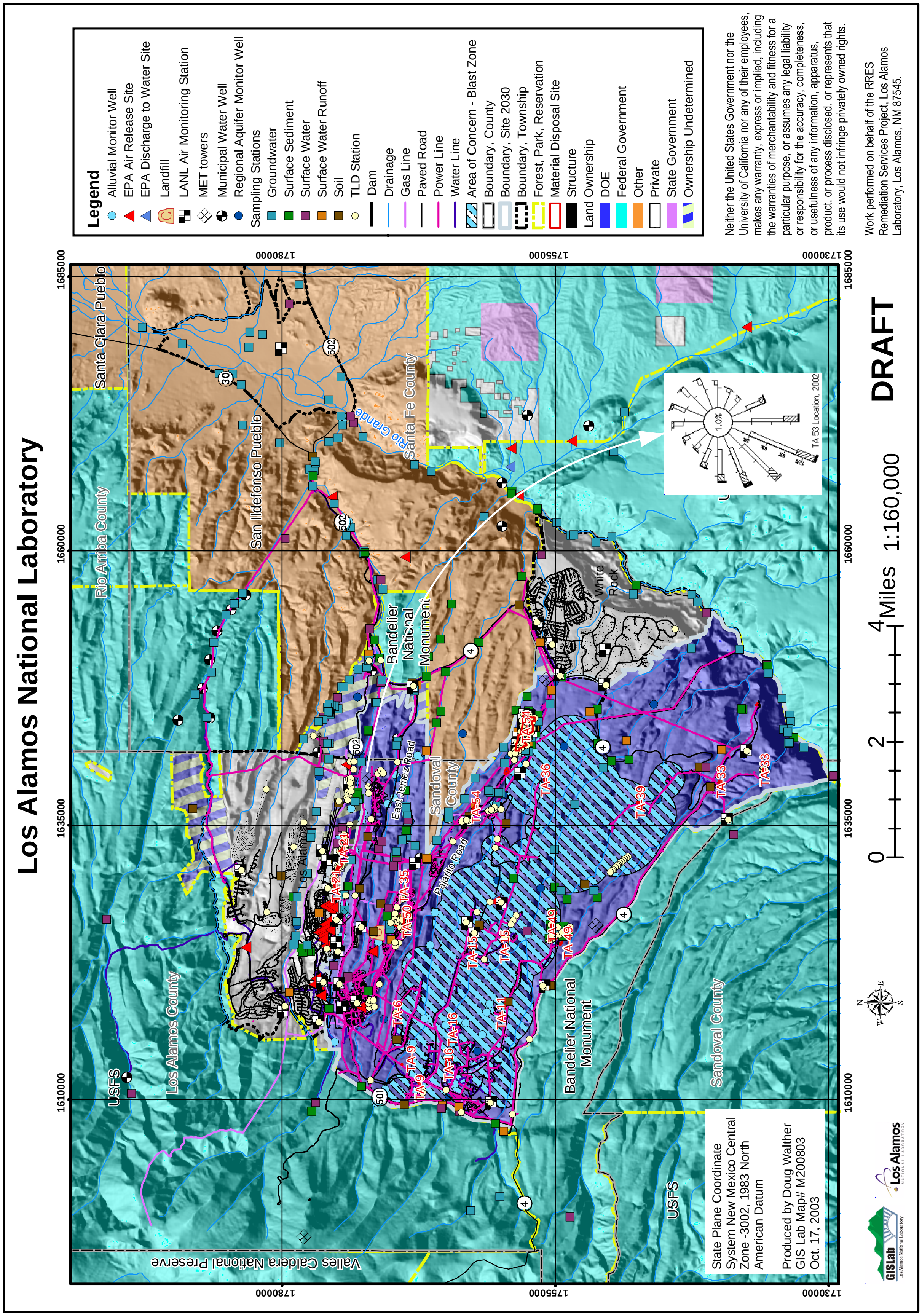


Figure 3.1b. Site physical and surface interface, End state.

- Sewage treatment facilities;
- Landfills; and
- LANL buildings and facilities.

With the exception of LANL buildings and facilities, no information was found to suggest major infrastructure changes between 2003 and 2035. LANL has initiated a major nuclear facilities consolidation program that will result in a dramatic change in the number and location of many of LANL's major buildings and facilities between 2003 and 2035. The data reflecting these changes are included in the maps, although they are not visible on the prescribed map format.

3.1.3 Surface Configuration

Based on DOE guidance, the site-wide Surface Configuration for LANL includes major topography and surface hydrology.

Rivers and streams located within 80 km (53 mi) of the Laboratory include the Rio Grande and its tributaries including the Chama, Ojo Caliente, Santa Cruz, Nambe, and Tesuque rivers to the north and east; the Jemez River and San Antonio creeks to the west; and the Santa Fe and Galisteo rivers to the south. The Rio Grande receives all surface water drainage from the Pajarito Plateau. Reservoirs within 80 km (50 mi) include the Cochiti, Abiquiu, Santa Cruz, and Jemez.

Despite the dramatic erosional topography of the Pajarito Plateau that resulted from greater surface flows in the past, only a few streams currently flow year-round; most flow only after heavy summer monsoonal rains and with spring snowmelt. Run-off from heavy rainfall and snowmelt reaches the Rio Grande several times a year in some watersheds.

Springs occur at elevations between 2,400- and 2,700-m (7,900- and 8,900-ft) on the eastern slopes of the Jemez Mountains and supply water to the upper reaches of several major watersheds. These springs discharge at rates from 7–530 l/min (1.8–140 gal./m), which is insufficient to maintain surface flow for more than the upper third of the watersheds before it is depleted by evaporation to the atmosphere and infiltration into the underlying alluvium. On the mesas, water flows only as stormwater and snowmelt run-off.

3.1.4 Hazard Areas of Concern

As represented in DOE's guidance, Hazard Areas of Concern include attributes contributing to the understanding of LANL hazards and potential exposures. Much of this information derives from the extensive sampling and monitoring conducted by LANL. In fact, the sampling and monitoring locations are among the most visible features on Figures 3.1a and 3.1b.

This section briefly describes the hazards associated with LANL operations and legacy contamination. Following, the current risks associated with both operational hazards and legacy hazards are characterized using recent monitoring data.

3.1.4.1 Operational Hazards

Operational hazards are associated with:

- Nuclear and radiological facilities,
- Biohazard facilities,
- Chemistry facilities, and
- Waste treatment, storage, and disposal facilities,

Currently, LANL has 18 nuclear facilities, as identified and categorized in accordance with the requirements of Title 10 Code of Federal Regulations, Part 830, *Nuclear Safety Management*, Subpart B, "Safety Basis Requirements." For each nuclear facility (which includes buildings, structures and processes), a formal safety analysis has been performed to identify hazards, and appropriate operational safety requirements have been developed to ensure facility safety. The approved safety basis documents for LANL's nuclear facilities ensures that the risks posed by those facilities and the nuclear materials therein are administratively controlled to the extent required by law.

Several of the nuclear facilities are legally permitted through NESHAPS and NPDES to release vapor-phase and effluents into the environment. Important among these are the beryllium machine shops and Radioactive Liquid Waste Treatment Facility. Permitted releases are monitored at points of discharge and at points down-gradient, both on and off site. Monitoring results are reported to the appropriate administrative authority, and are also published in the annual environmental surveillance report required by DOE.

One of LANL's nuclear facilities is a low-level radioactive waste disposal facility, known as Material Disposal Area G, MDA G, or simply Area G. An important part of MDA G's authorization basis is the performance assessment and composite analysis (PA/CA).

The DOE radioactive waste disposal sites are managed, in part, based on whether the sites were active before or after the issuance of DOE Order 5820.2A (September 25, 1988). DOE Order 5820.2A (superceded by DOE Order 435.1 in 2001) requires a radiological PA to demonstrate and document the safety basis for disposal sites accepting low-level radioactive waste (LLW) after September 25, 1988. The order defers radioactive waste disposal sites used before that date to either Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Resource Conservation and Recovery Act (RCRA) corrective action, with the latter applying at the Laboratory. To ensure that the cumulative radiological impact of all radioactive waste disposals will not adversely impact human health or the environment for future generations, a composite analysis (CA) is also required by the DOE.

The PA is required to determine if LLW generated since September 26, 1988 has been, and will continue to be, disposed at MDA G in a manner that will not result in radiation doses to the public that exceed performance objectives specified by the DOE. In a complementary fashion, the CA is used to evaluate options for ensuring that exposures from all radioactive waste disposed of at MDA G will not exceed specified limits in the future.

The PA/CA for MDA G is equivalent to a baseline human-health risk assessment for radiological constituents, evaluating environmental fate, transport, and human-health risk consequence of radioactivity disposed there. Consistent with DOE guidance, the all-pathways, all-sources risk analysis covers a time period of 1,000 years post closure.

The performance objectives for the PA that are comparable to RCRA and CERCLA risk assessment requirements are the following:

- Maximum effective dose equivalent of 25 mrem/yr. to any member of the public resulting from external exposure and concentrations of radioactive material released into surface water, groundwater, soil, plants, and animals.
- Maximum effective dose equivalent of 10 mrem/yr. to any member of the public from concentrations of radioactive material released to the atmosphere (excluding radon) from Area G and all other facilities at the Laboratory.
- Maximum effective dose equivalent of 4 mrem/yr. to any member of the public from the consumption of drinking water drawn from wells outside of the land-use boundary.

The performance objective for the CA is the DOE's primary annual dose limit of 100 mrem/yr.

The results of the PA/CA are compared to their associated performance measure in Table 3.1-1. By all measures, the PA/CA provides reasonable assurance that radionuclides released from MDA G will not exceed health-based standards, even when potential interacting releases from legacy MDAs are considered.

Table 3.1-1
Summary results of the MDA G performance assessment/composite analysis

Inventory	Analysis	Calculated Peak Dose	Performance Objective*
PA	Air pathway	6.6×10^{-2} mrem/yr.	10 mrem/yr.
CA	All pathways	5.8 mrem/yr.	30 to 100 mrem/yr.
PA	Groundwater protection	3.5×10^{-5} mrem/yr.	4 mrem/yr.
PA	All pathways	1.0×10^{-4} mrem/yr.	25 mrem/yr.
CA	All pathways	7.2×10^{-3} mrem/yr.	30 to 100 mrem/yr.

In addition to the nuclear facilities listed previously, there are numerous radiological facilities wherein radioactive materials are used, but under conditions that prevent risk-significant exposures. Like nuclear facilities, radiological facilities are identified through a formal process, but are exempt from safety-basis requirements. Still, safe operating procedures are required in radiological facilities to reduce the risk of harmful exposures.

The LANL integrated safety management system includes an authorization-basis requirement for facilities and processes that pose a non-nuclear hazard. Examples of non-nuclear hazards requiring non-nuclear authorization basis prior to initiating work are compressed-gas facilities and chemical operations facilities.

A significant operational hazard is identified over much of the southern portion of the LANL campus (light blue cross-hatching). This is the buffer zone associated with the firing sites, which are core mission facilities. As such, this buffer zone is expected to remain well into the future.

3.1.4.2 Legacy Contamination

Legacy contamination includes all of the sites being investigated and remediated under LANL's EM-sponsored cleanup program. The risk based end state achieved at the completion of the EM mission will ensure that performance standards (including a final site-wide risk goal) are met and maintained. This section briefly describes the general means by which those performance measures will be met to achieve the risk-based end state. The map shown on Figure 3.1b reflects the accomplishment of those general remedies, which include:

- remediation of surface and near-surface contamination to risk-based levels consistent with the planned future land use, either residential (for land parcels transferred to county or tribal governments), recreational (for land parcels transferred to the National Park Service or National Forest Service), or industrial/recreational (for land that will remain under the institutional management of LANL).
- capping and monitoring of MDAs, which will be transferred to NNSA for management.
- A site-wide groundwater monitoring program that will be implemented by NNSA.

Table 3.1-2 lists the number and general description of potential releases sites within each watershed, and indicates the planned remediation strategy and end state. The End State column indicates the planned remediation; the exposure scenarios that will be used in risk assessments supporting remediation plans; and the future landlord.

Table 3.1-2
Planned remediation end state for potential release sites

Watershed	Current Description	Contamination	End State
Los Alamos/Pueblo	63 potential release sites with residual contamination from surface waste disposal, explosives testing, wastewater	Rad, Inorganic, PCBs	Removal/ Based on Residential use soil cleanup levels/ Transfer to LA County or Tribal governments
	136 potential release sites with residual contamination from surface waste disposal, explosives testing, wastewater	Radiologic, Inorganic, Organic, PCBs	Removal/ Cap in place/ Based on Industrial and/or Recreational use soil cleanup levels for NNSA lands/ Monitoring systems installed/ transfer to NNSA
Mortandad	4 potential release sites attributed primarily to discharges of LANL wastewaters, which have occurred since 1951 and possibly as early as 1943, but also from runoff from mesa tops with LANL operations.	Perchlorate, Nitrate, Rad, Inoganic, PCBs	Removal/ Based on Residential use soil cleanup levels/ Transfer to LA County or Tribal governments
	169 potential release sites attributed primarily to discharges of LANL wastewaters, which have occurred since 1951 and possibly as early as 1943, but also from runoff from mesa tops with LANL operations.	Rad, Inorganic, Organic, PCBs	Cap in place/ Removal/ Based on Industrial and/or Recreational levels/ Monitoring systems installed/ transfer ownership to NNSA
Pajarito	172 potential release sites associated with secondary contamination from runoff from mesa-top operations	Rad, HE, Organic, Inorganic, perchlorate	Cap in place/ Removal/ Based on Industrial and/or Recreational levels/ Monitoring systems installed/ transfer ownership to NNSA
Sandia	76 potential release sites primarily associated with industrial and sanitary wastewaters and power plant cooling towerst	Rad, Inorganic, Organic, PCBs	Removal/ Based on Industrial and/or Recreational use soil cleanup levels/ Transfer ownership to NNSA
Water/Cañon de Valle	133 potential release sites primarily contaminated with debris from firing sites	Rad, Inorganic, HE	Removal/ Based on Industrial and/or Recreational use soil cleanup levels/ Transfer ownership to NNSA
Ancho	33 potential release sites primarily contaminated with debris from firing sites	Rad, Inorganic, HE	Removal/ Based on Industrial and/or Recreational use soil cleanup levels/ Transfer ownership to NNSA
Chaquehui	53 potential release sites associated with former firing areas and tritium site operations.	Rad, Inorganic, HE	Removal/ Based on Industrial and/or Recreational use soil cleanup levels/ Transfer ownership to NNSA
Frijoles	15 debris areas located in Bandelier National Monument.	Rad, Inorganic	D&D/ Based on Recreational use soil cleanup levels/ ownership NPS, NFS

Table 3.1-3 lists the legacy MDAs, along with a general description of the site and the planned remedy. The End State column indicates the planned remediation; the exposure scenarios that will be used in risk assessments supporting remediation plans; and the future landlord. The end state for the majority of the

MDAs is capping and monitoring, and transfer to NNSA. These are the sites for which long-term management will be required, as reported in DOE's 2001 *Long-Term Stewardship Study*.

The risk-based remedy-selection process developed for these MDAs is nearly identical to the performance assessment/composite analysis process that established the authorization basis for radioactive waste disposal at LANL's MDA G.[1] Indeed, seven of the legacy-waste MDAs (MDAs A, B, C, T, U, V, and AB) are included in the composite analysis for MDA G.[2] For this reason, LANL expects that the long-term institutional management of the legacy-waste MDAs can be integrated directly into the MDA G performance assessment/composite analysis maintenance program already implemented by NNSA, which is likely to be integrated within the LANL environmental management system.

Table 3.1-3

Planned remediation end state for MDAs

Watershed	MDA	Current Description	End State
Los Alamos/Pueblo	A	1.8-acre; two 50,000-gal. underground tanks and 3 pits	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	B	6-acre; primarily solid waste in shallow trenches; some chemical waste	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	T	3.5-acre; four radioactive liquid waste absorption beds and cemented-waste shafts	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	U	1.3-acre site; two absorption beds and associated sump	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	V	1-acre; three liquid absorption beds for outflow from radioactive laundry facility	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
Mortandad	C	11.8-acre; 7 pits and 108 shafts with solid radioactive waste	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	W	Two 4-in. diameter, 125-ft long stainless steel tubes suspended inside 8-in. diameter carbon steel–cased wells; tubes backfilled under pressure with nitrogen and sealed; 150L of liquid sodium reactor coolant contaminated with Pu-239 and associated fission products	Transferred to NNSA
	X	Buried LAPRE II reactor, decommissioned in 1959; site remediated in 1991	Transferred to NNSA
Pajarito	F	Classified trash	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	G	65-acre; 34 disposal pits, 174 disposal shafts with solid radioactive waste, 4 trenches with transuranic waste	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	H	0.3-acre; 9 shafts with radioactive and classified waste	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	I	2.65 acre; solid waste landfill	Transferred to NNSA
	L	2.5-acre; 1 pit, 34 shafts and 3 surface impoundments for liquid chemical waste in	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	M	Surface trash disposal site	Transferred to NNSA
	Q	Naval guns and other metallic trash	Cap and monitoring in place/ Industrial use/ Transferred to NNSA

[1] LANL provided NMED with a document describing the risk-based corrective action strategy for MDAs in 1999.
[2] Results of the composite analysis indicate that legacy MDAs are as robust as MDA G.

Watershed	MDA	Current Description	End State
Chaquehui	D	Two underground concrete chambers for HE	Transferred to NNSA
	E	Underground chamber plus 6 waste disposal pits; spent projectiles, U, Be	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	K	Septic tank, sump, roof drain and outfall; contaminants include tritium	Transferred to NNSA
Water/Cañon de Valle	N	< 1 acre; construction and office debris in shallow trenches	Remediated to Industrial and/or Recreational use standards Transferred to NNSA
	P	Surface site; HE burn-ground residues	Transferred to NNSA
	R	Surface site; HE burn ground and associated HE residues	Remediated to Industrial and/ore recreational use standards Transferred to NNSA
	Z	Approximately 2,000 yd of uranium-contaminated firing-site debris	Remediated to Industrial and/or recreational use standards Transferred to NNSA
	AA	13-ft deep trenches with burned and unburned firing site debris	Remediated to Industrial and/or recreational use standards Transferred to NNSA
Ancho	Y	5 shallow trenches with construction, office, and firing-site debris.	Remediated to Industrial and/or Recreational use standards Transferred to NNSA
	AB	Multiple 80-ft deep shafts with residue from noncritical nuclear weapons safety experiments	Cap and monitoring in place base on Industrial use Transferred to NNSA

Table 3.1-4 summarizes the current status of site-wide groundwater contamination and describes the planned remedy. The table includes three categories of groundwater, consistent with the site-wide hydrogeology: Alluvial, Perched, and Regional. The regional aquifer is the only source of drinking water for the local communities; alluvial and perched groundwater is not accessible. The supply wells are on LANL property, but are managed by the County of Los Alamos.

Table 3.1-4
Planned remediation end state for groundwater

Groundwater	Contaminants Detected	Remedy	End State
Alluvial	Nitrates, 15 mg/L Perchlorates, 3 ppb Strontium-90, 15 – 60 pCi/L Tritium, 15,000 pCi/L Molybdenum >1 mg/L	Reactive barriers, source removal, monitored natural attenuation, institutional controls over water use	Reduce contaminant levels for MCLSs or State standards so no 10^{-5} risk occurs in the regional aquifer. Transfer of groundwater monitoring and treatment systems to NNSA
Perched	High Explosives, 50 ppb Nitrates, 15 mg/L Perchlorates, 12 – 142 ppb Tritium 1,200 pCi/L	Institutional controls over the use of water, monitored natural attenuation, monitoring.	Long-term monitoring
Aquifer	High Explosives, 2 – 3 ppb Perchlorates, 6 ppb Nitrate 10 mg/L Tritium 350 pCi/L	Institutional controls over the use of well fields, Monitored natural attenuation, treat at the well head if necessary	Maintain Regional Aquifer as a drinking water supply without exceedences of 10^{-5} risk standards

The regional hydrogeology is being characterized through the installation of 32 wells extending to the regional aquifer. Table 3.1-5 lists the wells installed and planned as part of the regional hydrogeologic characterization program.

Table 3.1-5
Planned regional hydrogeology characterization wells

Watershed	Well
LosAlamos/Pueblo	R-5
	R-9
	R-7
	R-1
	R-8
	R-2
	R-3
	R-4
	R-6
Mortandad	R-15
	R-13
	R-14
	R-16
Water/Cañon de Valle	R-27
	R-28
	R-25
	R-29
	R-26
	R-24
	R-30
Sandia	R-12
	R-10
	R-11
Ancho	R-31
Pajarito	R-19
	R-22
	R-23
	R-18
	R-20
	R-17
	R-32
	R-21

LANL has completed a baseline probabilistic risk assessment and risk-based decision analysis model for Mortandad Canyon.[3] Similar models will be completed for each watershed. The watershed models will than be coupled to produce a site-wide groundwater decision analysis model that will be used to design (following systems-engineering principles) a site-wide monitoring program that will meet all of LANL's

[3] Preliminary results indicate a very low probability of exceeding EPA's threshold Hazard Index value of 1, excess cancer risk of 10^{-5}, or DOE's groundwater dose limit of 4 mrem, assuming a standard 70-year drinking-water exposure over a 100-year modeling period.

monitoring requirements in an integrated and cost-effective manner. Monitoring and monitored natural attenuation are expected to be the primary elements of the remedies for most contaminated groundwater locations at LANL. Ten monitoring wells are planned to fulfill the expected RCRA/HSWA monitoring obligations relative to historic releases and surface waste sites. These wells will monitor contaminant migration and contaminant levels downgradient of key liquid discharge locations, primarily in Los Alamos, Pueblo, Mortandad, and Water Canyons. Where possible, these wells will have supplementary benefits and may serve as multipurpose monitoring wells relative to material disposal areas (MDAs), RCRA units, and groundwater discharge plans. The optimal number and location of a subset of hydrogeologic characterization wells will be identified for long-term performance monitoring in support of EM completion, again using risk-based decision analysis methods.

3.1.4.3 Environmental Monitoring Summary

To ensure compliance with regulations and requirements related to major environmental statutes, LANL routinely monitors for radiation and radioactive and non-radioactive materials in environmental media, at both on- and off-site locations, all of which are identified on Figures 3.1a and 3.1b. Comparing monitoring results with applicable standards, LANL's environmental surveillance report routinely concludes that it is in compliance with all environmental regulations and does not pose a threat to its employees, member of the general public, or the environment. To support these conclusions, LANL completed the EPA OSWER's *Documentation of Environmental Indicator Determination*. These worksheets are included as an appendix to this document.

3.1.5 Significant Differences between the Current State and the End State Maps

The major difference in the attributes considered by DOE to represent Physical and Surface Interfaces now and in the year 2035 that are visible in Figures 3.1a and 3.1b is:

- The change in ownership of land in the north-central and north-northeast site-boundary in 2003 from Government in 2003 (grey outlined purple irregular polygon) to Ownership Undetermined in 2035 (purple cross-hatch), reflecting the planned transfer of land to either Los Alamos County or San Ildefonso Pueblo.

3.2 Human and Ecological Land Use

This section discusses the human and ecological attributes presented in maps following DOE's prescribed format. Figure 3.2a represents current conditions (i.e., 2003), while Figure 3.2b represents end-state conditions (i.e., 2035).

As discussed in DOE's guidance, human and ecological land use attributes fall into the following three categories:

- Human Activities,
- Ecological Activities, and
- Hazard Areas of Concern.

3.2.1 Human Activities

Human activities include site-wide and local land-use and water-use patterns, which can be used to identify potential points, pathways, and scenarios of human exposure to potentially contaminated media. Characteristic differences in human activities (and therefore potential exposures) are expected in agricultural, residential, commercial, industrial, recreational, open-space, and restricted-access areas.

The majority of the land within the LANL boundary (grey line) land is designated as Open Space (dark blue) or Manufacturing and Industrial (magenta). The industrial space is only sparsely populated with buildings and structures associated with LANL operations. While not visible on the prescribed map format, the topography within and around the LANL site effectively limits amount of land suitable for facilities. Generally speaking, LANL buildings are on mesas rather than in canyons. This is also true for residential, municipal, and commercial structures in the Town of Los Alamos. Since the topography of the region is not expected to change significantly between 2003 and 2035, this general rule is expected to hold true.

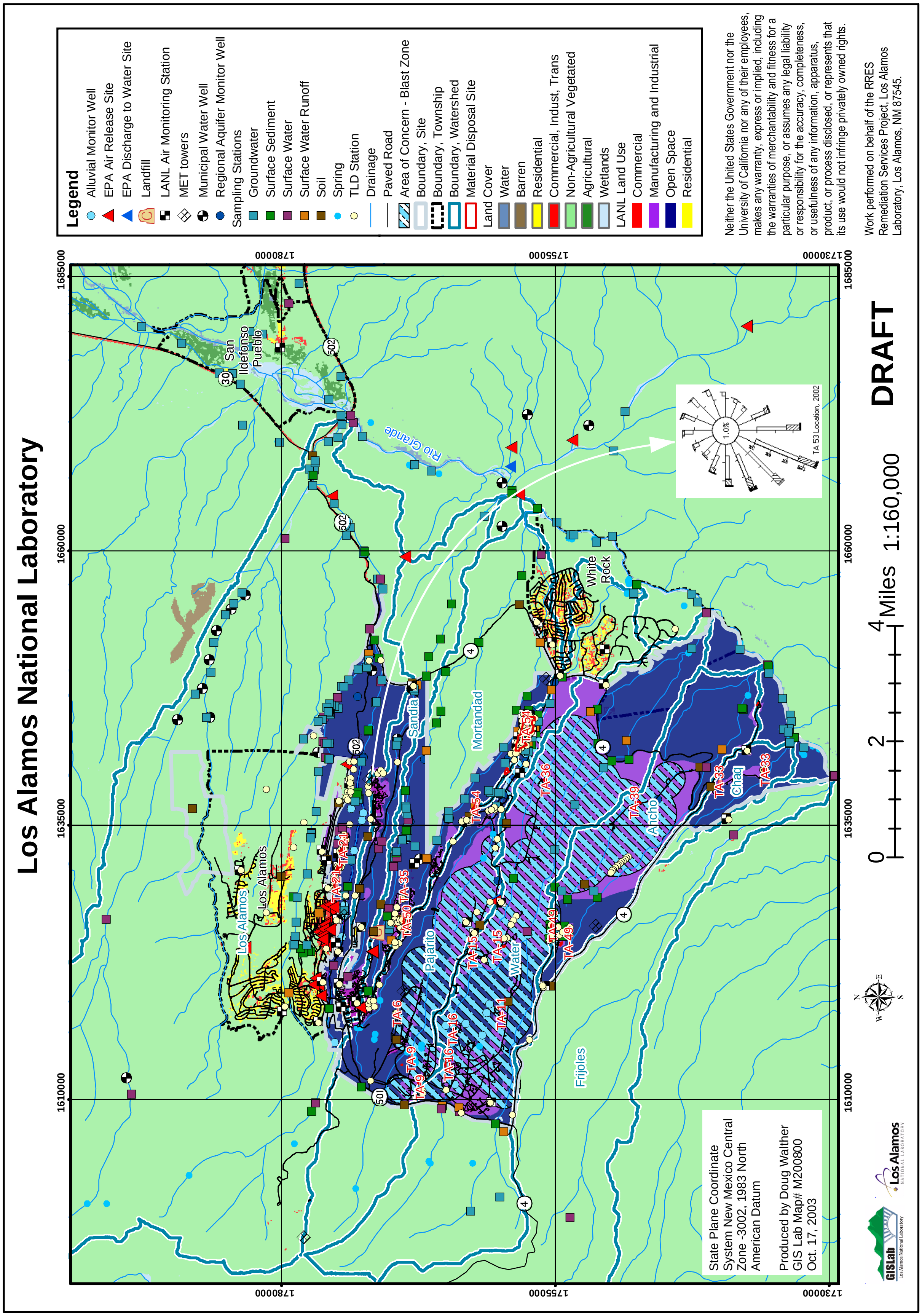


Figure 3.2a. Site human and ecological land use, Current state.

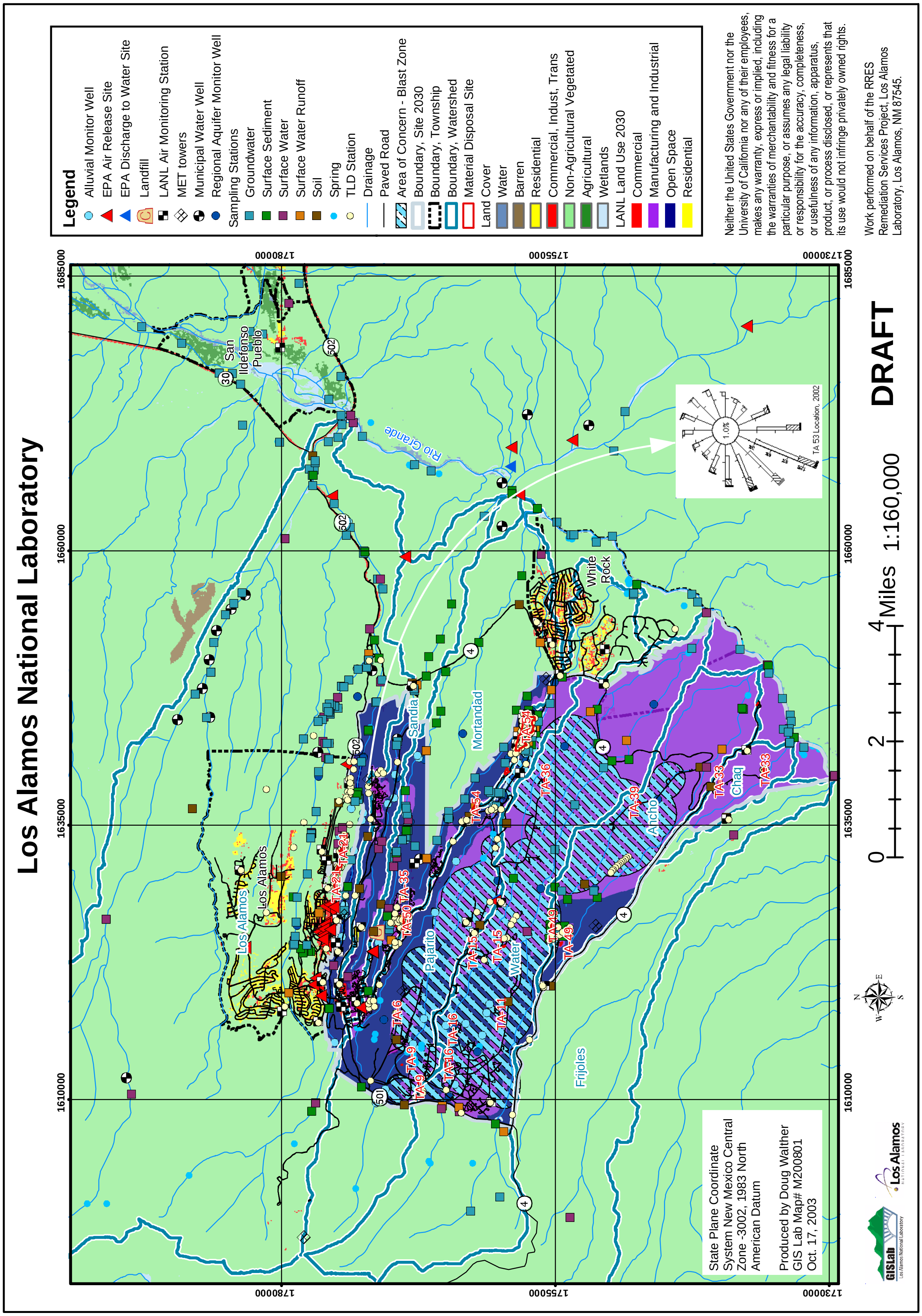


Figure 3.2b. Site human and ecological land use, End state.

In 2035 as in 2003, vacant land designated as Non-Agricultural Vegetated (light green) dominates all other categories of land use around LANL, accounting for 49 percent of the area. Recreational use of accessible lands for hiking, mountain-biking, rock-climbing, and snow-skiing is prevalent, and is expected to remain so.

Due to the semi-arid climate and the local topography, agricultural activities in the area around LANL are limited and are expected to remain so. However, the community of San Ildefonso Pueblo located west-northwest of LANL between highway 30 and highway 502 grows crops for domestic consumption and some local marketing, and also graze livestock on their lands near the LANL boundary.

The following points summarize local agricultural activity:

- A small percentage of land (1 to 2 percent) is used for growing crops.
- Most of the agricultural acreage is irrigated.
- Surface water irrigation is much more common than groundwater irrigation.
- Livestock density is low (1 per 300 acres).

Information regarding anticipated changes in the two population centers (the town of Los Alamos adjacent to the north-central site boundary, and the town of White Rock near the west-central site boundary) were not available at the time that these maps were created, but they are not expected to grow significantly since they are largely populated by families of LANL employees and the number of employees is not expected to increase dramatically.

The municipal water supply for both Los Alamos and White Rock is maintained with water pumped from the regional aquifer, which is approximately 300 m below-ground-surface. The supply wells are operated and maintained by the county of Los Alamos, but are located on LANL property. Water pumped from the wells is stored in above-ground tanks.

The Rio Grande is used extensively for recreational purposes, including fishing and rafting. It is the only significant surface water body near the LANL environs.

3.2.2 Ecological Activities

Ecological activities suggestive of potential ecological exposure points and receptors are partially inferred from knowledge of local conservation areas, threatened and endangered species buffer zones, watersheds, wetlands, vegetation coverages, and habitat ranges.

The plants and animals native to the Los Alamos region designated as Non-Agricultural Vegetated (light green) are diverse, partly because of the large elevation gradient between the Rio Grande (1500 m above sea level) and the Jemez Mountains (2,100 m above sea level) and also because of the canyon and mesa terrain. One-seed juniper and piñon pines are the dominant tree species in undisturbed areas. Common shrub species include big sagebrush (Artemisia tridentata), wax currant (Ribes cerceum), four-wing salt bush (Atriplex canescens), currant (Ribes sp.), and mountain mahogany (Cercocarpus betuloides).

Blue grama grass (Bouteloua gracilis), cryp-togamic soil crust, and prickly pear cactus (Opuntia spp.) are the most common low-growing (understory) plants on the mesa top. Other common understory plants include snake weed (Gutierrezia microcephala and Gutierrezia sarothrae), pinque (Hymenoxys richardsonii), wild chrysanthemum (Bahia dissecta), leafy golden aster (Chrysopsis filiosa), purple horned-toothed moss (Ceratadon purpureus), several lichen species, three-lawn grass (Aristida spp.), bottlebrush squirreltail (Sitanion hystrix), bluegrass (Poa spp.), false tarragon (Artemisia dracunculus), and a species of Mammalaria cactus.

As a result of LANL operations, many of the native under-story plants within the LANL boundary are being replaced by exotic species. Recently disturbed areas support plants such as goosefoot (Chenopodium fremontii), tumbleweed (Salsola kali), cutleaf evening primrose (Oenothera caespitosa), common sunflower (Helianthus anuus), and other colonizing species.

Insects, reptiles, mammals, and birds inhabit the Pajarito Plateau. Harvester ants are the most abundant insect, while common reptiles include fence lizards (Sceloporous undulatus), Plateau striped whiptails (Cnemidophorus velux), gopher snakes (Pituophis melanoleucus), and garter snakes (Thamnophilis elegans). Many mammals inhabit the Pajarito Plateau, including rodents, mule deer, elk, black bear, mountain lion, bobcat, fox, and coyote. The plateau supports a wide variety of bird species. In addition to a range of songbirds, a variety of nesting and migrating raptors have been identified in less-disturbed areas of the canyons. Burrowing animals are common to the mesa tops across the Plateau.

3.2.3 Significant Differences between the Current State and the End State Maps

The major visible differences in the attributes considered by DOE to represent Human and Ecological Land Use now and in the year 2035 are:

- The change in land-use designation from Open Space in 2003 (dark blue) to Manufacturing and Industrial in 2035 (magenta-pink) in the southern-most portion of the LANL boundary.
- The reduction of land within the north-central (grey outlined light green irregular polygon) and north-northeast (dark blue "hook") site-boundary in 2003, shown as Non-Agricultural Vegetated (light green) in 2035, corresponding to land parcels that will be transferred from DOE within the next decade.

3.3 Site Context Legal Ownership

The maps shown in Figures 3.3a and Map 3.3b show the current and predicted legal ownership of the lands surrounding LANL. Refer to section 3.1.1 for additional details on land ownership and control. The major differences between the maps representing the current state and the end state are associated with land transfer, as discussed earlier.

3.4 Site Context Demographics

The maps shown in Figures 3.4a and Map 3.4b show the current and predicted population density of the lands surrounding LANL.

3.5 Conceptual Site-Wide Exposure Model

A conceptual site-wide exposure model identifies potential sources of contamination, relevant pathways for transport, and likely pathways for exposure based on current knowledge of the distribution of contaminants in environmental media. The transport pathway descriptions include the predominant release mechanisms, transport processes, and the contaminated media for each transport pathway.

This section begins by describing characteristics of the natural environment within which LANL operates that play a role in the risks posed by contaminants released in air or on or below the land surface. Figure 3.5 is a false-color satellite image of the site, which illustrates the rather dramatic surface features that impact the transport of contamination within the environment, and therefore play a major role in controlling the risks associated with environmental hazards. Some of the more important impacts associated with the hydrogeology include:

- The mesa-canyon topography; which affects air, surface water, and subsurface contaminant transport, as well as potential contaminant receptors.
- The geology, consisting of subsurface layers of various volcanic depositions, which has variable physical and chemical features that affect subsurface contaminant transport.
- The hydrology, incorporating intermittent surface streams in adjacent canyons, liquid- and vapor-phase water moving through the subsurface within the rock matrix, within fractures in the rock, and along interfaces between layers, and from transpiration, all of which affect surface and subsurface transport of contaminants.

That narrative description is followed by a graphical depiction of the conceptual site-wide exposure model, which identifies environmental processes that may transport contaminants within the environment, potentially resulting in harmful exposures. The conceptual site-wide exposure model groups the hazards discussed previously in this section into generic Hazard Categories, which are:

- Hazard Category A: Airborne (largely operational hazards, including stack emissions, burning sites, and explosives-firing sites)
- Hazard Category B: Surface (both operational and legacy sources including liquid effluents, chemical spills, intact waste containers, and industrial and manufacturing operations)

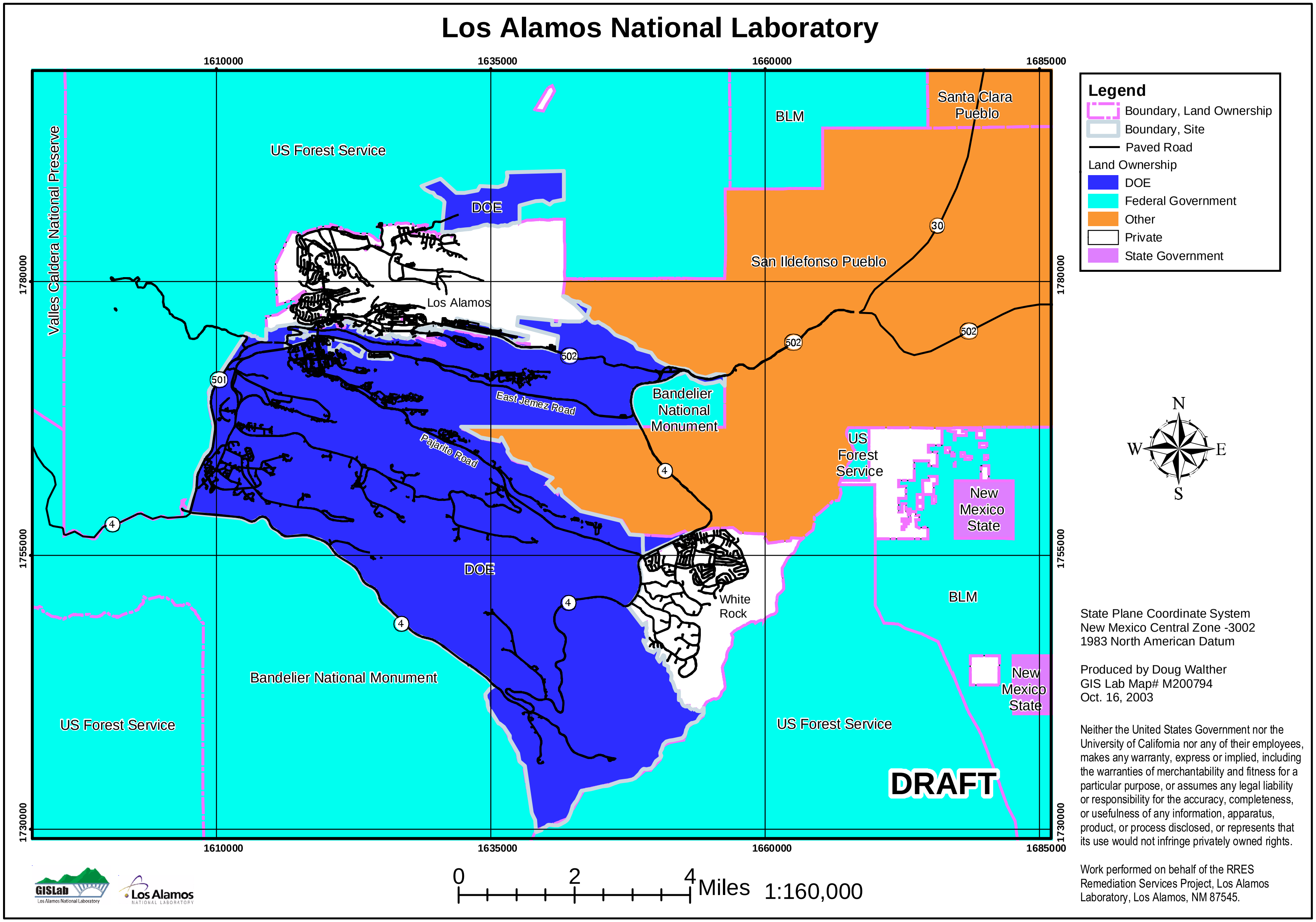


Figure 3.3a. Site legal ownership, Current state.

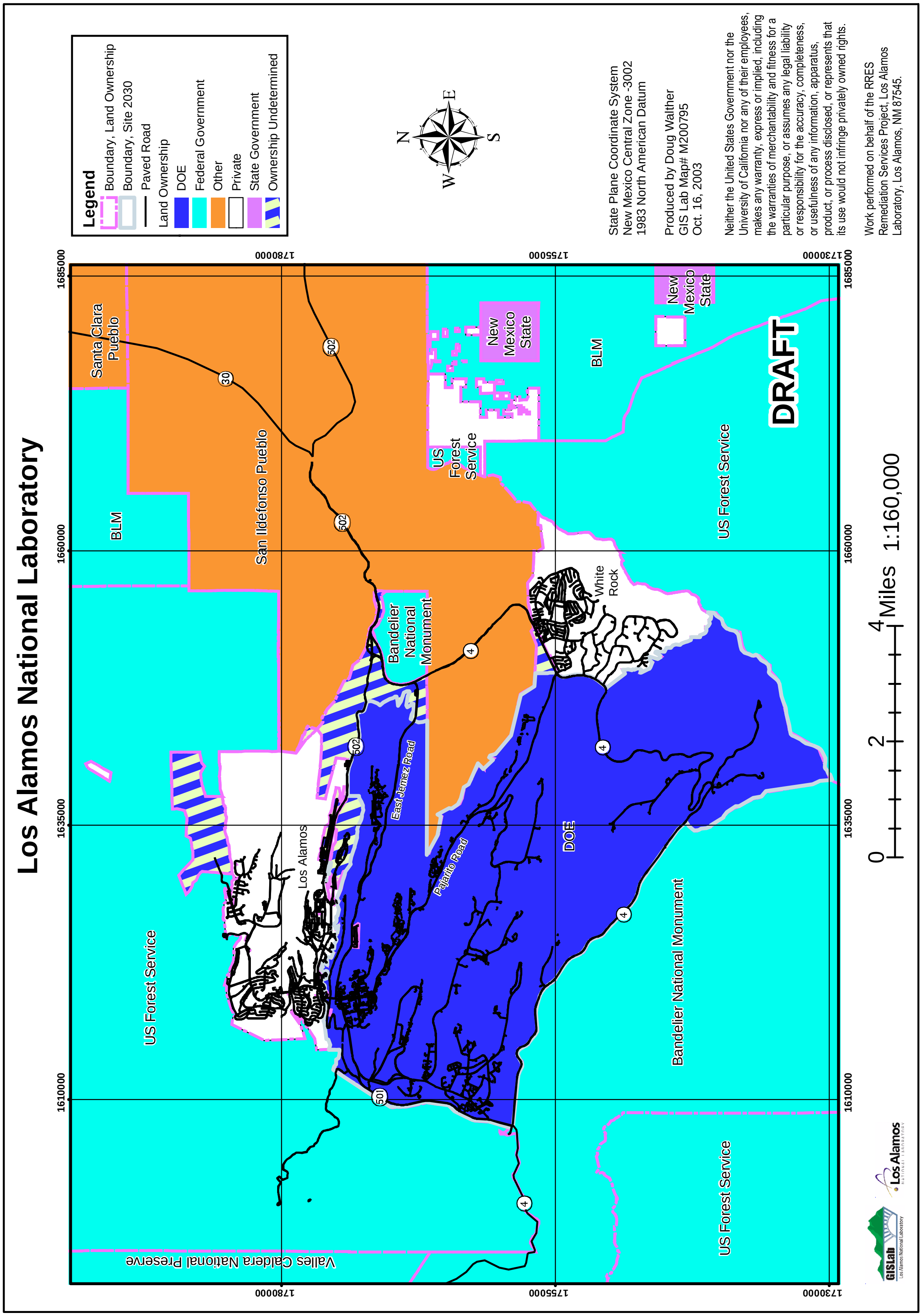


Figure 3.3b. Site legal ownership, End state.

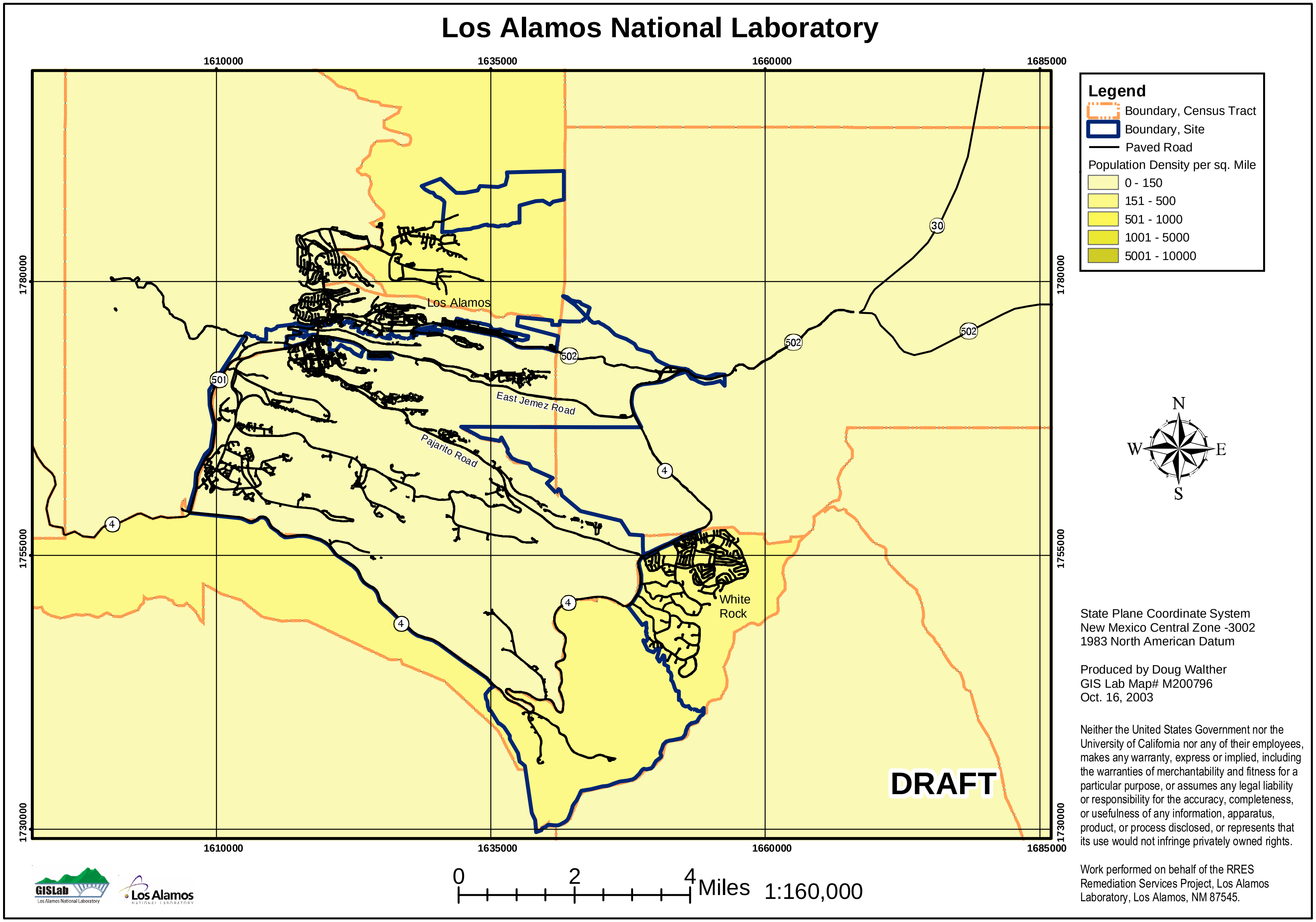


Figure 3.4a. Site demographics, Current state.

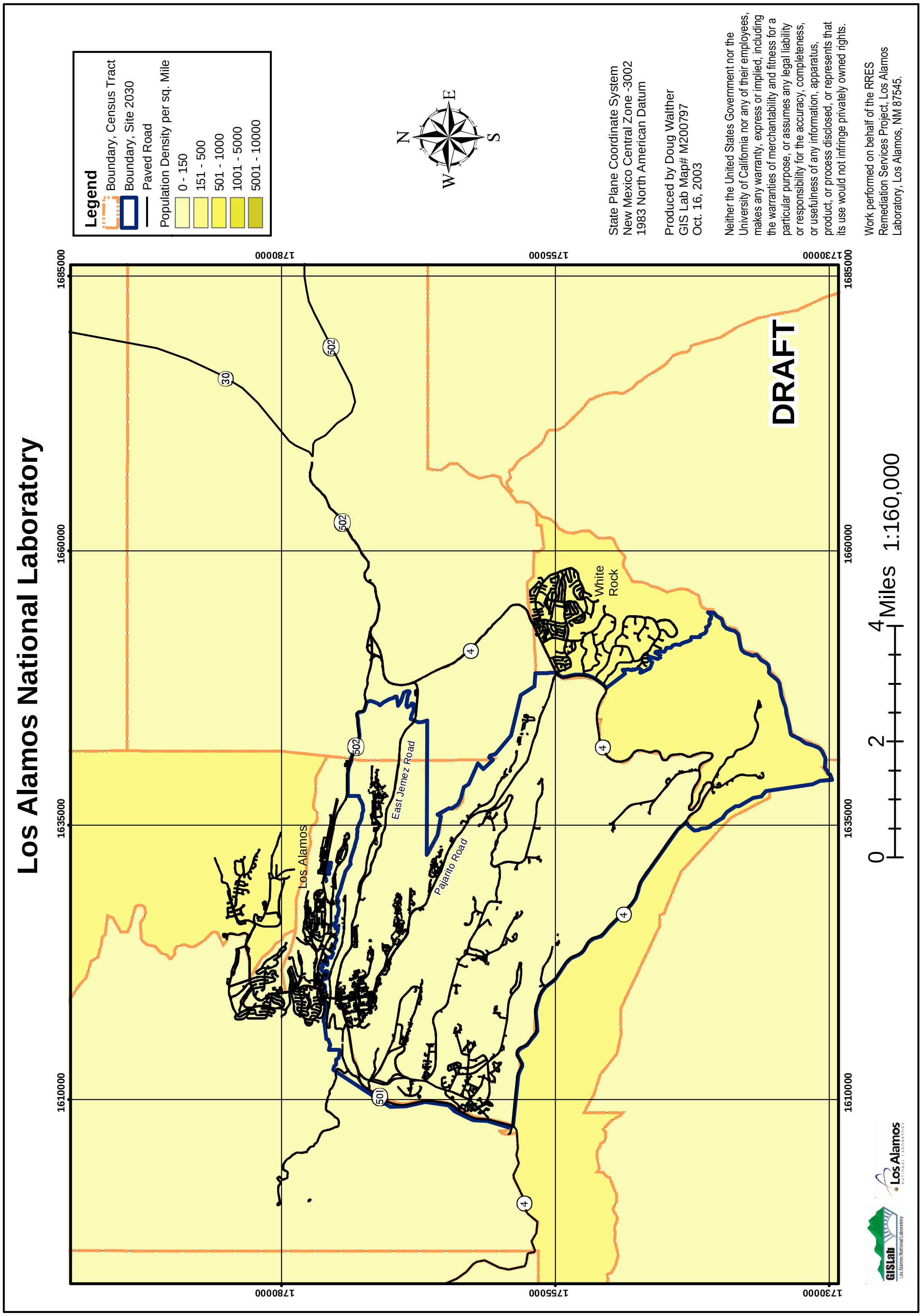


Figure 3.4b. Site demographics, End state.

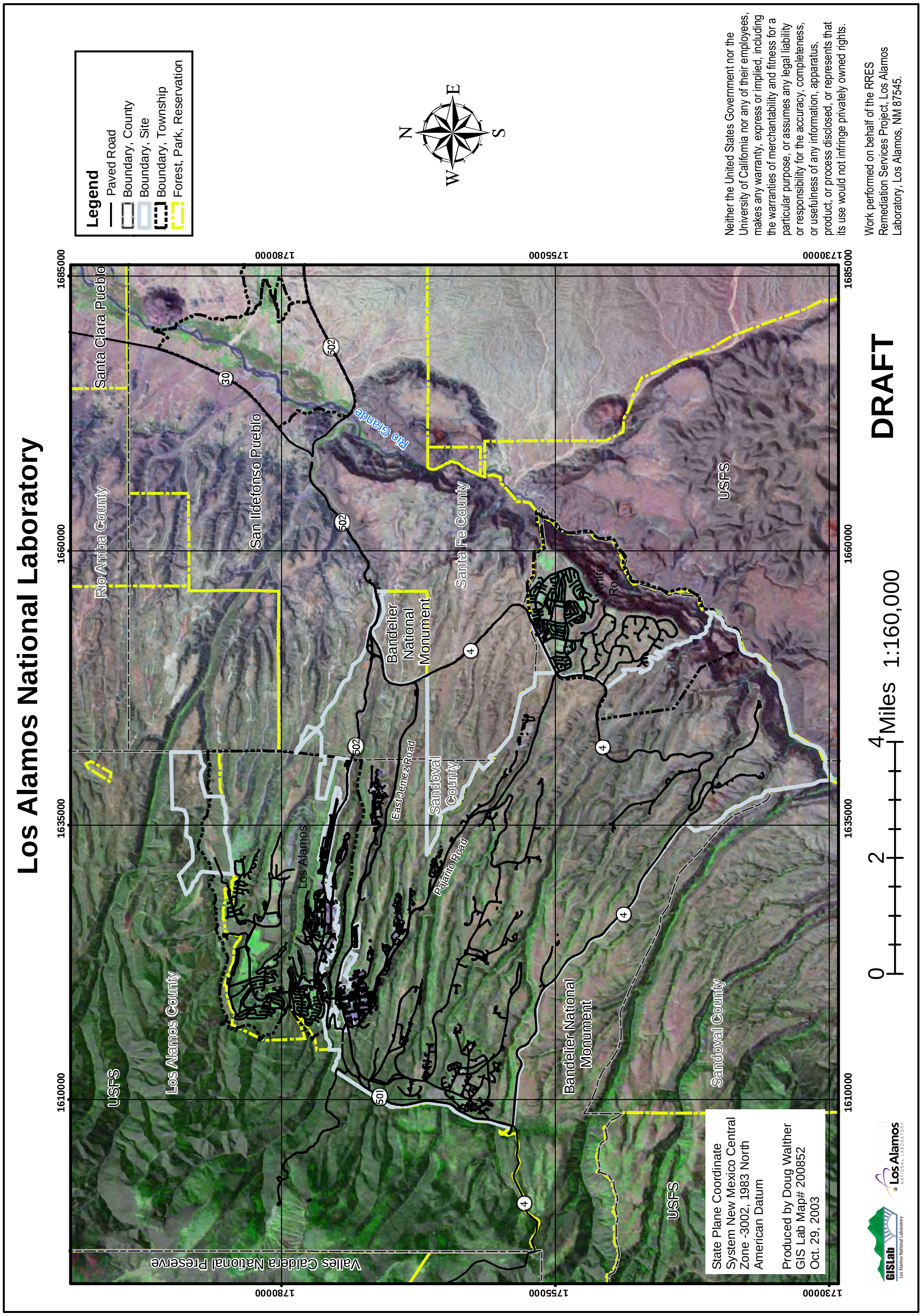


Figure 3.5. Site Landsat photo and surface interface.

- Hazard Category C: Subsurface (both operational and legacy sources including MDAs, septic tanks, and evaporation lagoons).

Environmental Setting

LANL is located on the Pajarito Plateau in north central New Mexico. The 43 mi^2 (112 km^2) plateau slopes gently to the east-southeast between the Jemez Mountains on the west and the broad Grande Valley on the east, which runs north to south. Elevations range from 7600 to 6300 ft (2317 to 1920 m) above mean sea level. The local relief of the plateau consists of east-southeast-trending canyons and mesas. This section of the document describes the natural features and events of the region, focussing on those that may impact the release or transport of contaminants.

<u>Climate</u>

The Pajarito Plateau has a temperate semiarid mountain climate. Spring is typically windy and dry. Summer begins with warm, usually dry conditions in June, followed by a two-month rainy season in July and August. The rainy season ends in autumn when the climate becomes drier, cooler, and calmer, and winters are generally mild with occasional winter storms.

Meteorological variables at the Laboratory are measured at five towers on the Pajarito Plateau. Four of the towers are located on mesas and one tower is located in Los Alamos Canyon. Local and regional topographical features significantly influence the local meteorology of the LANL area (Baars et al. 1998,

The elevation of the Pajarito Plateau is the primary influence of temperature; the plateau is cooler in the summer than the surrounding low-lying desert. In the evenings and at night, cool air sinks off the plateau and flows down the canyons; thus, nighttime temperatures on the mesas are often warmer than in the

canyons and at lower elevations. The general lack of moisture in the atmosphere also influences temperature. With less moisture, there is less cloud cover, which allows a significant amount of solar heating during the daytime and radiative cooling during the nighttime. This heating and cooling causes a wide range of daily temperatures. The average range is 13°C (LANL 1998, 59904).

The average annual precipitation, from rainfall and the water equivalent from frozen precipitation, is 47.6 cm (18.7 in.). However, the annual total fluctuates considerably from year to year, with the standard deviation of the fluctuation being 12.2 cm (4.8 in.). The lowest recorded annual precipitation is 17.3 cm (6.8 in.) and the highest is 77.1 cm (30.3 in.). The maximum precipitation recorded for a 24-h period is 8.8 cm (3.5 in.) and the maximum for a 15-minute period is 2.3 cm (0.9 in.). The eastern portion of the plateau often receives 13 cm (5.1 in.) less annual precipitation than the west-central portion of the plateau. About 36% of the annual precipitation falls during the July/August rainy season.

Winter precipitation occurs mostly as snow. The annual snowfall averages 150 cm (59 in.) but from year to year the amount of snow is quite variable. The highest recorded snowfall for one season is 389 cm (153 in.), and the highest recorded snowfall for a 24-h period is 56 cm (22 in.). In a typical winter there are 14 days during which snowfall exceeds 2.6 cm (1 in.) and 4 days of snowfall exceeding 10.2 cm (4 in.). The most extreme single-storm snowfall on record is 122 cm (4 ft).

Relative humidity varies considerably daily, but monthly averages vary little during the year. Relative humidity ranges from 39% in June to 56% in December, and averages 51% over the entire year. Absolute humidity ranges from 2.4 g of water/m^3 of air in January to 8.7 g/m^3 in July and August, when moist subtropical air invades the region during the rainy season. Fog in the Pajarito Plateau area is very rare, occurring less than five times a year on average.

Wind conditions on the Pajarito Plateau are generally light, and the average annual wind speed is 2.5 m/s (5.5 mi/h). However, the windy season from mid-March to early June sustains wind speeds exceeding 4 m/s (8.8 mi/h) 20% of the time during the day and the daily maximum wind gust exceeds 14 m/s (31 mi/h) about 20% of the time. The highest wind gust on record is 343.4 m/s (77 mi/h). Tornadoes have not touched the ground in the Pajarito Plateau area; however, funnel clouds have been observed in Los Alamos and Santa Fe Counties.

Winds over the Pajarito Plateau show considerable spatial structure and temporal variability. During sunny, light-wind days, an upslope flow greatest along the western margin of the plateau usually develops over the plateau in the morning. By midday a southerly flow usually prevails over the entire plateau.

The prevailing nighttime winds over the western portion of the plateau are west-southwesterly to northwesterly. These nighttime westerlies result from cold air drainage off the Jemez Mountains and the Pajarito plateau; the drainage layer is typically 50 m (165 ft) deep in the vicinity of Technical Area (TA) 6. At stations farther from the mountains, the nighttime direction is more variable but usually has a relatively strong westerly component. Just above the drainage layer, the prevailing nighttime flow is usually southwesterly.

Observations made at meteorological stations in canyons show that atmospheric flow there is quite different from flow over the mesas. During the nighttime, cold air flows down the canyons about 75% of the time. This gravity flow is steady and continues for an hour or two after sunrise when it abruptly ceases and is followed by an unsteady up-canyon flow for a couple of hours.

Solar irradiance measurements show that Los Alamos receives more than 75% of possible sunshine annually. (Possible sunshine is defined as the amount received when the sky is cloud-free.) During most of the year, when there is no snow on the ground, about 80% of this incoming solar energy is absorbed at the ground surface. About half of this absorbed shortwave energy is offset by longwave radiation to space. The remainder of the radiant energy, called the net all-wave radiation, is dissipated into the soil, into the lower layer of the atmosphere, and evaporates water from the soil and plants (evapotranspiration). Preliminary analyses suggest that monthly total evapotranspiration reaches a maximum of 7.4 cm (2.9 in.) in July. Monthly totals during January and February are about 0.8 cm (0.3 in.). It appears that evapotranspiration equals approximately 90% of the annual precipitation.

Geology

The surface distribution of bedrock geologic units in the Pajarito Plateau area is shown on geologic maps The principal bedrock units in the Pajarito Plateau area consist of the following, in ascending order:

- Puye Formation: and basalts of the Cerros del Rio volcanic field on the east.
- Otowi Member of the Bandelier Tuff and volcaniclastic sediments of the Cerro Toledo interval
- Tshirege Member of the Bandelier Tuff

The Puye Formation is mostly a fanglomerate deposit generally consisting of poorly sorted boulders, cobbles, and coarse sands. At PM-3 the clasts are composed of dacite, rhyolite, and fragments of basalt and pumice. At TW-8 in Mortandad Canyon, the fanglomerate consists predominately of fine- to coarse-grained sands and interbedded clay, silt, and gravel. The lower fanglomerate includes more than 95 ft (29 m) of light tan to light gray tuff and tuffaceous sand.

The top of the regional zone of saturation beneath the Pajarito Plateau is usually encountered within the fanglomerate facies of the Puye Formation and the associated interbedded basalts.

The Otowi Member of the Bandelier tuff erupted approximately 1.6 million years ago. The Otowi Member varies in reported thickness from 184–465 ft (56–142 m). The deposits of the Otowi Member beneath upper Sandia and middle Mortandad watersheds are among the thickest on the Pajarito

The basal part of the Otowi Member includes the Guaje Pumice Bed, which is a sequence of well-stratified pumice-fall and ash-fall deposits. The Guaje Pumice Bed typically is 30- to 35- ft- (9.1- 10.7-m) thick beneath the Pajarito Plateau.

The Tshirege Member of the Bandelier Tuff erupted approximately 1.2 million years ago. It is a multiple-flow ignimbrite sheet that forms the prominent cliffs and mesas of the Pajarito Plateau. The Tshirege Member includes a number of subunits that can be recognized based on differences in physical and weathering properties.

Subunits of the Tshirege Member dip gently southeastward on the Pajarito Plateau. The southeastward dip of these tuffs probably is the primary initial dip, mainly resulting from the burial of a southeast-dipping paleotopographic surface and thinning of subunits away from the volcanic source to the west.

Hydrology

Rivers and streams located within 80 km (53 mi) of LANL include the Rio Grande and its tributaries including the Chama, Ojo Caliente, Santa Cruz, Nambe, and Tesuque rivers to the north and east; the Jemez River and San Antonio creeks to the west; and the Santa Fe and Galisteo rivers to the south. The Rio Grande receives all surface water drainage from the Pajarito Plateau. Reservoirs within 80 km (50 mi) include the Cochiti, Abiquiu, Santa Cruz, and Jemez.

Despite the dramatic erosional topography of the Pajarito Plateau that resulted from greater surface flows in the past, only a few streams currently flow year-round; most flow only after heavy rains and snowmelt. Run-off from heavy rainfall and snowmelt reaches the Rio Grande several times a year in some drainages.

Springs occur at elevations between 2,400- and 2,700-m (7,900- and 8,900-ft) on the eastern slopes of the Jemez Mountains and supply water to the upper reaches of several major canyons, which is depleted by evaporation to the atmosphere and infiltration into the underlying alluvium. On the mesas, water flows only as stormwater and snowmelt run-off. As a result of run-off, surface erosion occurs, typically as shallow sheet erosion on the relatively flat parts of the mesa, or by local established erosion channels during sustained storm run-off.

Run-off from summer storms reaches a maximum in less than 2 hours and lasts less than 24 hours. In contrast, run-off from spring snowmelt occurs over a period of several weeks at a low discharge rate. The amount of eroded material transported in run-off waters is generally higher in summer rainfall events than during snowmelt.

Groundwater in area occurs as shallow perched alluvial groundwater in canyons, intermediate perched zones beneath some canyons and along the Jemez Mountains within the Bandelier Tuff, the Cerros del Rio Basalt, and the upper part of the Puye Formation, and in the regional aquifer. The regional aquifer is the only source capable of serving municipal and industrial water needs.

Ephemeral streamflows in the canyons of the Pajarito Plateau have deposited alluvium that locally may be up to 100-ft-(30 m) thick and typically more permeable than the underlying volcanic tuff and sediments. Ephemeral run-off in some canyons infiltrates the alluvium until downward movement is impeded by the less permeable underlying strata, which results in a buildup of shallow alluvial groundwater. In addition to the alluvium, in some cases relatively thin zones of shallow groundwater can also be contained in the weathered tuff or some other unit immediately underlying the alluvium.

Perched groundwater is known to exist beneath several canyons in the eastern portion of the Laboratory, along the eastern flanks of the Jemez Mountains west of the Laboratory, and beneath the mesas and canyons at S Site (TA-16), located in the southwestern part of the Laboratory near the Jemez Mountains. Perched groundwater zones possibly exist beneath other canyons in the south and central portions of the Laboratory.

Water for LANL, the communities of Los Alamos and White Rock, and Bandelier National Monument is supplied from 11 deep wells in 3 well fields. The wells are located on the Pajarito Plateau and in Los Alamos and Guaje canyons east of the plateau. Municipal and industrial water supply pump volume during 1997 was 1.29 billion gal. (4.9 billion l). Yields from individual wells ranged from about 175–1400 gal./min (665–5320 l/min) (Stoker et al. 1992, 12017).

Typically, most of the units of the Tshirege Member, which form the mesas and slopes on the Plateau, are very dry and do not readily transmit moisture. However, relatively thin subunits such as pumice falls, surge beds, and the Colonnade Tuff demonstrate elevated moisture contents and enhanced fluid-flow properties. Most of the pores in the tuff are small enough to be of capillary size, and hold water against gravity by surface tension forces. Moisture content is generally more variable near the top of the mesa than in the central portions as a result of variations in temperature, humidity, and evapotranspiration. Vegetation is very effective at removing moisture near the surface by transpiration. During the summer rainy season when rainfall is highest, near-surface moisture content is variable due to the effects of higher rates of evaporation and of transpiration by vegetation, which flourishes during this time.

The volumetric moisture content within mesas varies between about two and 14 percent. Measurement on core samples show that the surge beds at the base of Unit 2 have relatively high capillary suction and low hydraulic pressure. The interpretation of these measurements is that moisture is being drawn towards the surge beds from above and below. The driving force for this movement may be evaporation aided by air movement along the fractures within these units or along the more permeable surge beds found at the base of Unit 2. Similar surge beds are found at the Unit 3/4 interface, also; less is known about the air permeability there.

3.5.1 Current State

Figure 3.5.1a is a conceptual site-wide exposure model, which integrates in a simple diagram the features, events, and processes characterizing the current state, as discussed in the previous sections, in the specific context of risk- the likelihood of harmful exposures to contaminants in the environment. The Hazard Category box on the left side of the figure represents contaminants that are introduced directly into:

- air (Hazard Category A),
- onto the surface of the ground (Hazard Category B), or
- below the surface of the ground (Hazard Category C).

Hazard Categories are analogous to what are loosely referred to as primary sources, recognizing the subtlety that sources become hazards when they enter the environment. Under current conditions, Hazard Categories A and B are associated primarily with operational releases discussed in Section 3.1.4, while Hazard Category C is associated with both active and formerly-used MDAs.

The arrows emanating from each Hazard Category represent environmental transport pathways that may move contamination from the directly affected medium to one or more media, which become indirectly contaminated, represented by the boxes to the left of center on the figure. The arrows between indirectly

contaminated media represent the systematically integrated pathways that may move contamination within the environment. The arrows pointing right from the indirectly contaminated media to the matrix on the right of the figure indicate exposure pathways whereby biological receptors may come into contact with contaminated media. Several of the pathways are particularly important because they provide natural controls (discussed below) over the movement of contaminants. Generally speaking, these natural controls reduce potential exposure-point concentrations to levels below applicable regulatory or risk-based standards.

The line-styles of the arrows differentiate between pathways that are fully controlled (········▶), partially controlled (--▶), and uncontrolled (—▶). As apparent from the figure 3.5.1a, controls [||) can be achieved at any point between the Hazard Category and the exposure point. Controls that occur at the hazard source are examples of EPA's Source Control Performance Measure (cf. Section 1.3.1).

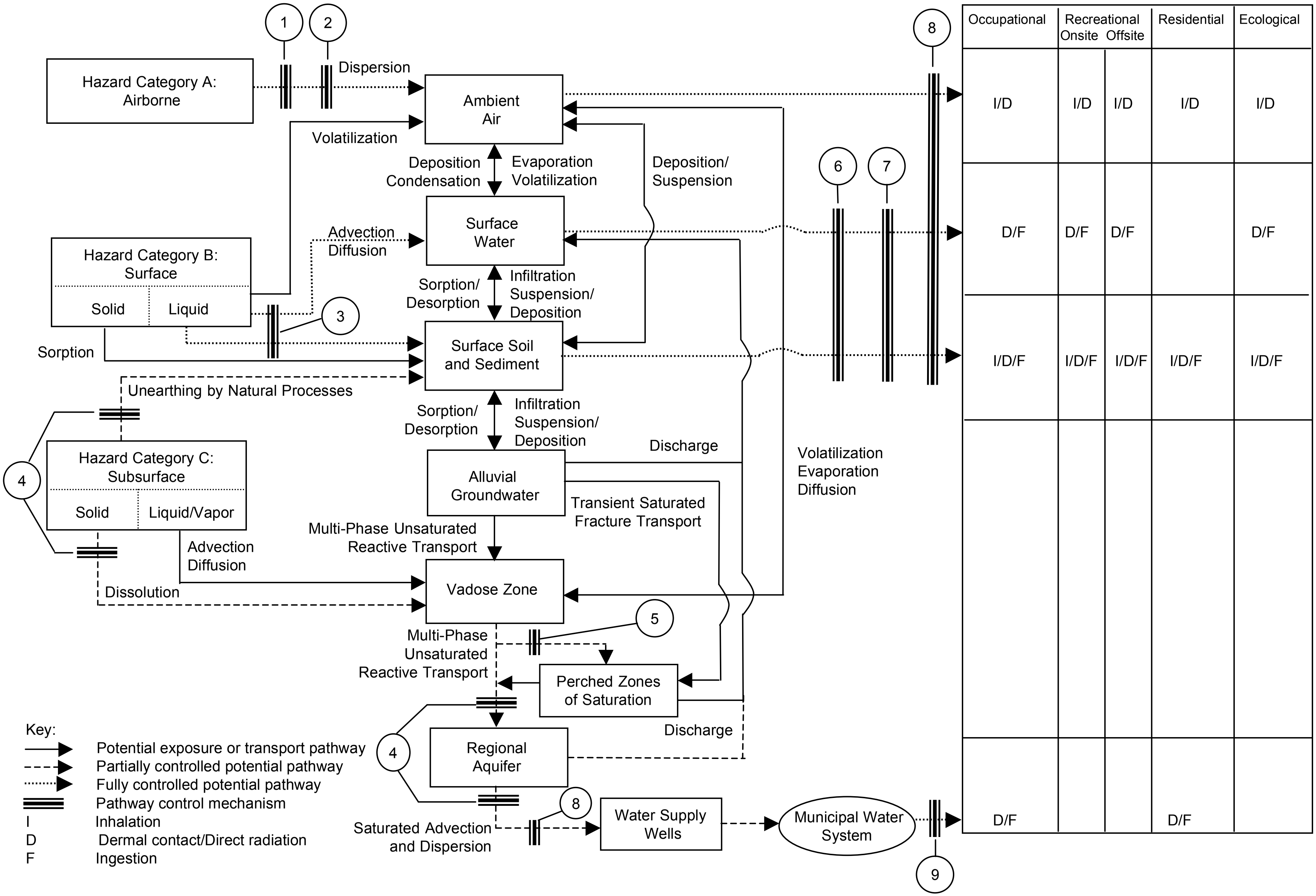
The site-wide conceptual site exposure model shows a number of controls that reduce the risk of hazards under current conditions. Many of these are associated with institutional and administrative controls pursuant to worker safety and environmental protection regulations, while others are attributed to natural characteristics or process at the site that attenuate hazards along the pathway between hazard and receptor. Together, institutional and natural controls provide layers of protection that ensure that the risks due to operational and historical releases of contamination into the environment from LANL are relatively low, as demonstrated on the RCRA Environmental Indicators worksheets included in Appendix 1.

The number tagging each control mechanism in Figure 3.5.1a identifies each control as follows:

1. Source control and monitoring of operational releases of hazardous constituents to air in compliance with NESHAPS regulations provide control of hazard.

2. Source control and monitoring of operational releases of hazardous particulates in air in compliance with OSHA provide control of hazard.

Figure 3.5.1a Site-Wide Conceptual Site Exposure Model– Current State



3. Source control and monitoring of operational releases of waste water in compliance with NPDES regulations provide control of hazard.
4. Characterization of regional hydrogeology, and monitoring conducted in association with the risk and performance assessment/composite analysis and environmental protection programs provide evidence of natural pathway control, indicating that multiphase unsaturated reactive transport and saturated advection and dispersion ensure that most contaminants (i.e., all but non-reactive species) will *not* be transported from their source to groundwater exposure points by 2035.
5. Characterization data show no perched zones of saturation beneath material disposal areas, but not all have been investigated, providing partial evidence of transport pathway control.
6. Through natural processes, surface water transport of dissolved species is partly retarded by adsorption onto sorptive phases in solid media. Through administrative health and safety procedures, risk-significant worker-exposures to contaminated water, soil and sediment are controlled.
7. Through natural processes, concentrations of contaminants in sediments generally decrease downstream along watersheds (i.e., toward the LANL boundary) due to dilution with clean sediments. Through administrative controls, access at facility boundary provides partial control of potential recreational exposures.
8. Exposure control provided by environmental protection program monitoring and mitigation of potential contamination in air, soil, sediment, groundwater, and springs.
9. Exposure control provided by monitoring of municipal water supply.

Table 3.5-1 provides a contextual definition of each of the indirectly contaminated media, and descriptions of and hypotheses associated with, the pathways included in Figure 3.5.1a.

Table 3.5-1.
Definitions, descriptions, and hypotheses of media and pathways in the current-state site-wide conceptual exposure model

Indirectly Contaminated Medium	**Contextual Definition**
Ambient Air	Refers to the earth's atmosphere as a media for contaminant transport.
Surface Water	Includes perennial and ephemeral stream reaches (both naturally occurring and effluent-driven), groundwater discharged via springs, surface impoundments and ponds, and stormwater flow derived from short, intense, precipitation events and snowmelt.
Surface Soil and Sediment	Includes naturally occurring soil and anthropogenically placed backfill materials present on mesa tops, and soils and sediments present on mesa slopes and canyon bottoms, both naturally occurring and derived from mesa tops.
Vadose Zone	Unsaturated media located between the ground surface and locally present groundwater, whether the groundwater is present at alluvial, intermediate, or regional aquifer depths.
Alluvial Water	Unconfined surface or near-subsurface zones of saturation in unconsolidated surface sediments in canyons, perched high above the regional aquifer.
Perched Zones of Saturation	Includes occurrences of perched groundwater bodies of varying extent and depth.
Regional Aquifer	Groundwater present in the regional zones of saturation, which typically occur in the Puye Formation, sediments of the Santa Fe Group, Cerros del Rio Basalts, and the Tschicoma Formation.
Transport or Exposure Pathway	**Description/Hypothesis**
Advection	Dissolved contaminants moving with the bulk flow of water.
Condensation	Concentration and settling of vapor-phase airborne contaminants onto surface media.
Deposition	Gravity-driven settling of suspended particulate contaminants from air or surface water onto surface media, or from groundwater onto solid confining solid media.
Desorption	Re-dissolution of solutes that were bound to solid phases of geologic media.
Diffusion	Movement of dissolved contaminants in liquid water and volatile contaminants in air from areas of higher concentration to areas of lower concentration.
Discharge	Groundwater migrating to the surface due to physical forces
Dispersion	Atmospheric distribution of airborne contaminants controlled by temperature and pressure gradients, wind speed and direction, and precipitation, and surface- and groundwater distribution of solutes in a saturated conditions.
Dissolution	Chemical reaction with surface water or groundwater, causing a solid-phase contaminant to disperse into liquid water as a solute.
Evaporation	Conversion of liquid water and volatile contaminants to vapor phases due to contact with ambient air. Pore water evaporation appears to occur deep within mesas due to barometric pumping.
Infiltration	Flow of surface water and solutes into surface media through pores or small openings.
Matrix (unsaturated) flow	Steady-state movement of liquid water and solutes, and colloids smaller than the pore space, through the pore spaces in unsaturated rock.
Microbial Degradation	Decomposition by microscopic organisms.
Mineralization	Organic materials naturally transformed into inorganic materials.
Multi-Phase Unsaturated Reactive Transport	Matrix transport coupled with contaminant-specific processes like radioactive decay, microbial degradation, sorption/desorption, mineralization, and evaporation.

Transport or Exposure Pathway	Description/Hypothesis
Sorption	Dissolved contaminants in subsurface binding to natural components of the solid porous media, and onto the surface of soil and sediment particles that can be transported by runoff and concentrated in depositional areas in the canyons.
Suspension	Precipitation runoff, surface water flow, and effluent discharge moving contaminants as particles into the canyon stream or groundwater.
Transient Saturated Fracture Transport	Relatively rapid infiltration, transient flow, and transport in the subsurface through cooling joints and faults in bedrock.
Unearthing by Natural Processes	Re-exposure of subsurface materials by natural processes such as (but not limited to) biotic intrusion, surface erosion, and mass wasting. *Anthropogenic excavation is excluded*.
Volatilization	The direct release of solutes to the atmosphere.

The columns in the matrix on Figure 3.51 indicate the land-use scenarios under which exposures may occur under current conditions, and the letters within the matrix cells indicate the routes of exposure consistent with the exposure scenarios and exposure pathways.

3.5.2 End State

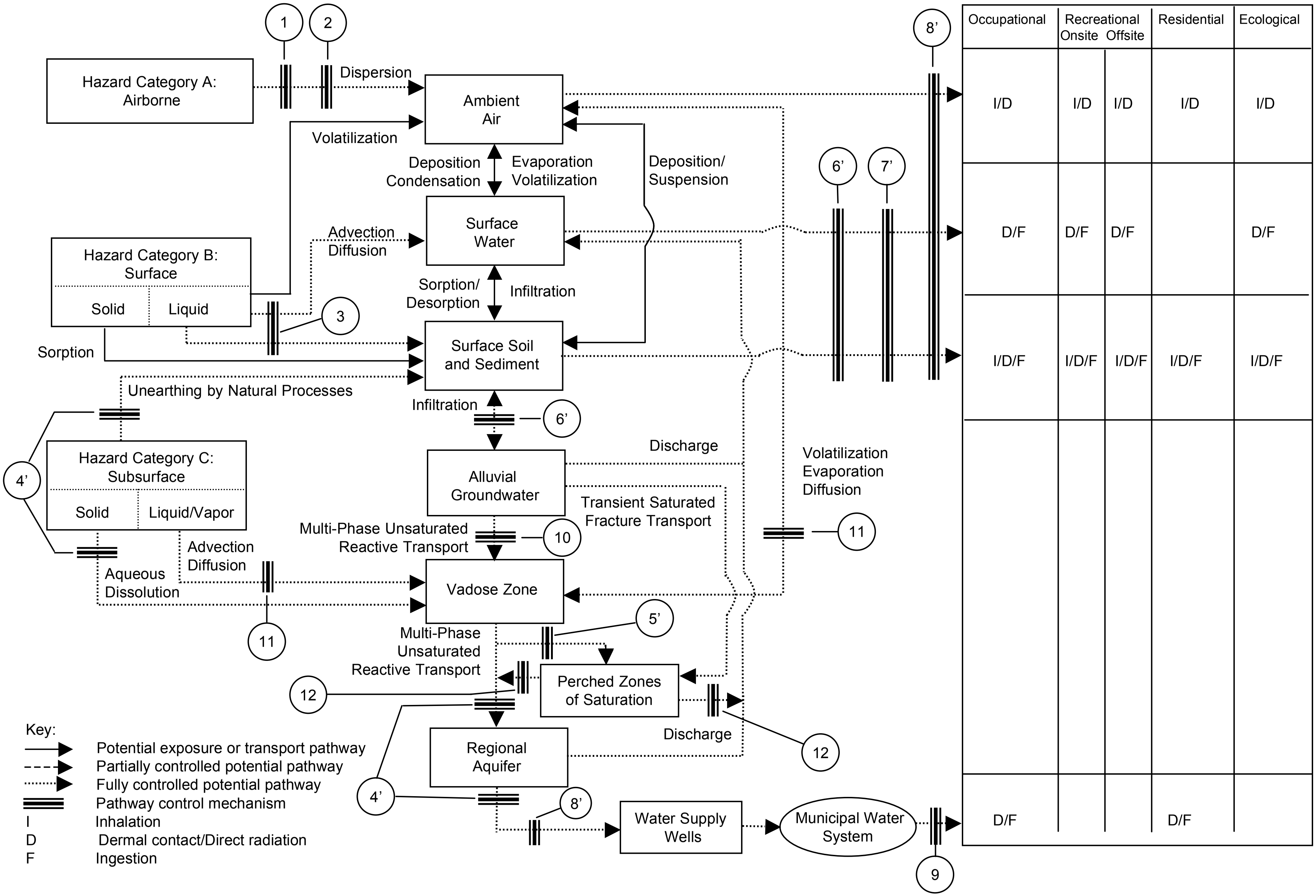
Figure 3.5.1b shows the conceptual site-wide exposure model for end-state conditions expected to be achieved through LANL's EM-sponsored cleanup project and maintained through LANL's NNSA-sponsored environmental management system (which will incorporate long-term environmental stewardship responsibilities, as discussed in Section 1.3.5). The potentially impacted media and transport and exposure pathways active in the current state conceptual exposure model and listed in Table 3.5-1 apply equally to the risk-based end state.

Many of the uncontrolled and partially controlled transport and exposure pathways identified in the current-state are fully controlled. The numbers with prime symbols (i.e., 1' through 8') signify enhancements of controls identified in the current state conceptual site-wide exposure model. In particular, the institutional monitoring and mitigation will meet the requirements of DOE Order 450.1 for systematic site-wide monitoring to ensure the early identification of, and appropriate response to, potential adverse environmental impacts associated with DOE operations, including effluent and surveillance monitoring. Consistent with guidance on annual reporting of site-wide monitoring, results will be differentiated according to NESHAPS and NPDES compliance monitoring, remediation performance monitoring, waste management monitoring, and environmental surveillance monitoring.

1. Source control and monitoring of operational releases of hazardous constituents to air in compliance with NESHAPS regulations provide control of hazard.
2. Source control and monitoring of operational releases of hazardous particulates in air in compliance with OSHA provide control of hazard.
3. Source control and monitoring of operational releases of waste water in compliance with NPDES regulations provide control of hazard.

4'. Characterization of regional hydrogeology, and monitoring conducted in association with the risk and performance assessment/composite analysis and environmental protection programs provide evidence of natural pathway control, indicating that multiphase unsaturated reactive transport and saturated advection and dispersion ensure that most contaminants (i.e., all but non-reactive species) will *not* be transported from their source to groundwater exposure points by 2035. Major MDAs are capped and monitored within the institutional environmental management system. Groundwater is monitored to detect contaminants at specific levels and locations established to provide time to respond before contaminants reach supply wells, springs, or the Rio Grande.

Figure 3.5.1b Site-Wide Conceptual Site Exposure Model– End State



5’. Perched zones beneath material disposal areas are characterized and accounted for in risk-based end state (including regulatory standards and final risk goal).

6’. Through natural processes, surface water transport of dissolved species is partly retarded by adsorption onto sorptive phases in solid media. Contaminated soil and sediment removed, treated, or stabilized as necessary to achieve risk-based end state (including regulatory standards and final risk goal).

7’. Through natural processes, concentrations of contaminants in sediments generally decrease downstream along watersheds (i.e., toward the LANL boundary) due to dilution with clean sediments. Institutional access controls are enhanced, as necessary to achieve end-state risk goal (including regulatory performance standards and final risk goal).

8’. Exposure control provided by environmental protection program monitoring and mitigation of potential contamination in air, soil, sediment, groundwater, and springs. An integrated site-wide groundwater-monitoring program will be designed and implemented to ensure early detection of risk-significant contaminants from all Hazard Categories as necessary to maintain the end-state risk goal.

9. Exposure control provided by monitoring of municipal water supply.

10. Contaminated alluvial groundwater treated and monitored as necessary to achieve end-state risk goal (including regulatory performance standards and final risk goal).

11. Subsurface vapor sources are controlled by soil vapor extraction as necessary to meet source-control performance standards, and MDAs are monitored and contingency responses implemented as necessary to achieve risk-based end state (including regulatory standards and final risk goal).

12. Contaminated perched zones are monitored and contingency responses implemented as necessary to achieve risk-based end state (including regulatory standards and final risk goal).

4 HAZARD SPECIFIC DISCUSSION

This section describes, using figures and text, the chemical and radiological hazards associated with LANL operations, past, present, and future. The eight watersheds named in Section 1.3 of this document are represented as "hazard areas." There are two maps for each hazard area, one representing the current state (i.e., 2003) and another representing the projected end state 20 years after completing the EM mission (i.e., 2035). For each map, there is an associated conceptual site exposure model. The conceptual models describe the release, transport, and potential exposure pathways for each of the hazard categories (A, B, or C) present within each hazard area. Hazard categories share a common fate in the environment, and have a potential for impacting a common receptor. The descriptions of affected media and transport and exposure pathways provided in Table 3.5-1 apply to all of the conceptual site exposure models in this section, as do the controls identified in the conceptual site-wide exposure model for the current state and the risk-based end state (cf Figures 3.5b1 and 3.5b2).

Aerial orthophotographs for each hazard area are also presented. These are present to aid in the understanding of surface hydrology and geology/topography.

Using a LANDSAT image, Figure 4.0.1 provides a frame of reference for the individual hazard-area maps that follow. This map assigns each watershed a number corresponding to the order in which they are discussed in the following subsections. It also gives a sense of the site-wide morphology, which plays an important role in the transport and fate of contaminants in the environment. (Note that the order of presentation does not correspond with the order of priority discussed in Section 1.)

4.1 Hazard Area 1: Los Alamos/Pueblo Watershed

The Los Alamos/Pueblo watershed (identified as 1 on Figure 4.0.1) covers a significant portion of the northern LANL area, extending from the western to the eastern borders. It is an east trending canyon that originates on US Forest Service land at an elevation of 9950 ft asl. The drainage extends about 16 mi from the headwaters to its confluence with the Rio Grande at an elevation of 5550 ft asl, and has a drainage area of about 17.5 mi^2. This drainage crosses San Ildefonso Pueblo land for about 3.5 mi before joining the Rio Grande. The canyon passes through or is adjacent to several of LANL's Technical Areas.

The watershed is 600 to 3000 ft wide at the top and varies in depth from 200 to 800 ft. It cuts into Bandelier Tuff across LANL property, and into the Puye Formation before it reaches the Rio Grande. The canyon floors are relatively flat, are filled with alluvium and colluvial soils eroded from the canyon walls, and vary in width from a few tens of feet to 2000 ft. The sides of these canyons are steep and rocky, and are partially covered by trees, particularly on the south sides (the north-facing slopes).

On a regional scale, Los Alamos/Pueblo watershed is an interrupted stream characterized by extremely variable flow. Two springs in the uppermost reaches of the watershed support a perennial reach to within a few to several hundred yards. On LANL property, surface water flow is mainly ephemeral above the Los Alamos County Sewage Treatment Plant, which typically supports surface flow to the eastern LANL boundary. Two springs just east of the boundary, and one spring in the lower canyon, flow intermittently and provide surface water to the stream and saturation in the alluvium. Springs, effluent flow, and precipitation, combined with seasonally variable saturated alluvial conditions in the lower canyon can support surface flow to the Rio Grande several days of the year.

4.1.1 Current State

The current state of hazards, hazard controls, and exposure controls in the Los Alamos/Pueblo watershed are described in this section. For clarity, the Hazard Categories defined in Section 3.5 are used. Hazard Category maps and associated conceptual site exposure models are both presented.

(Refer to Section 3.5.1 for detail on the general elements of the conceptual site exposure model.)

Figure 4.1a1 shows the existing airborne discharges (Hazard Category A) within Los Alamos/Pueblo watershed, and the associated conceptual site exposure model. Current airborne sources include exhaust emissions and open-air firing sites. The map shows wind roses, which indicate the predominant daytime and nighttime wind directions, hence the dominant directions of airborne dispersion. The map

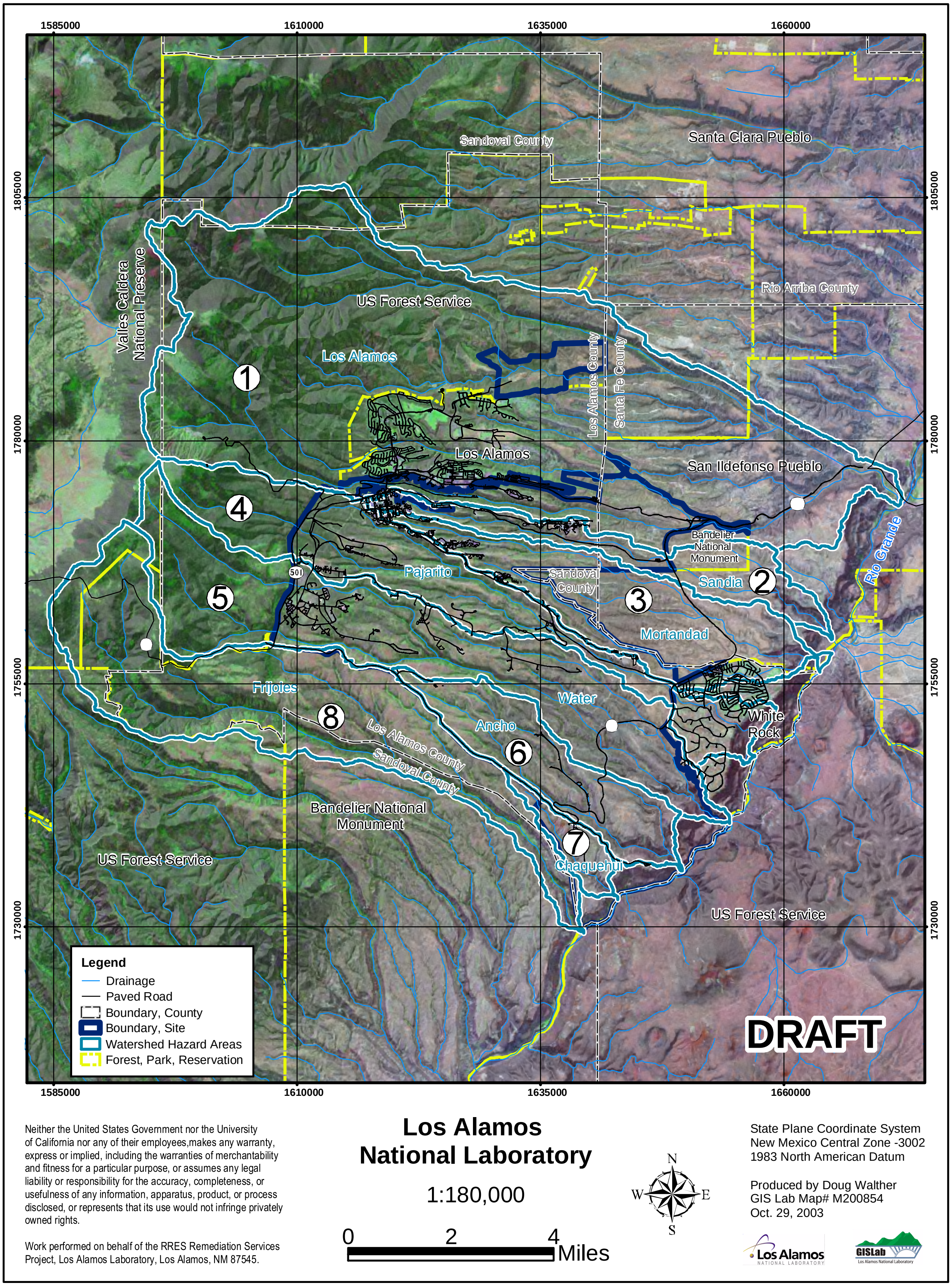


Figure 4.0.1. Site-wide hazard map Landsat photo and surface interface.

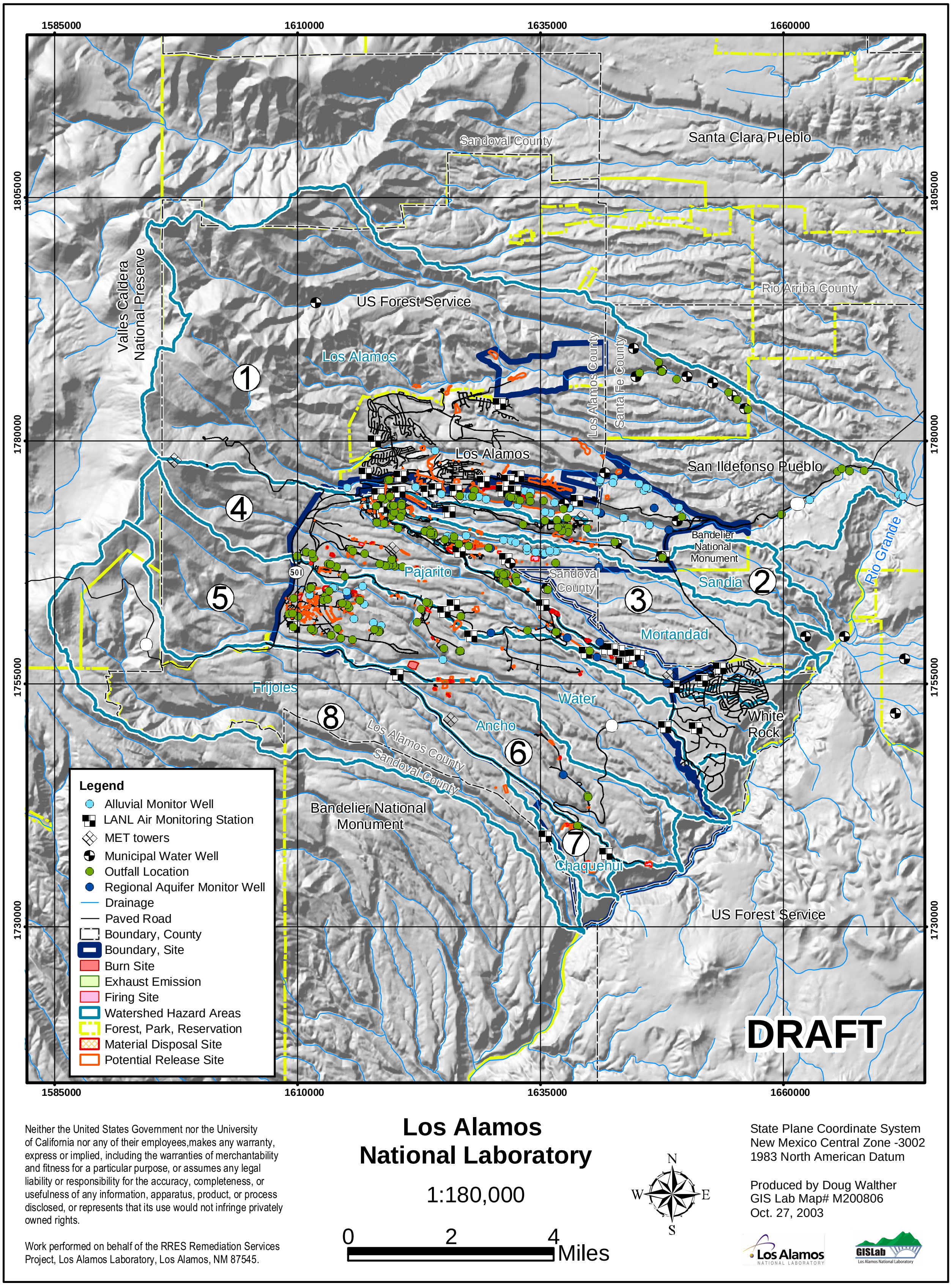


Figure 4.0a. Site-wide hazard map, Current state.

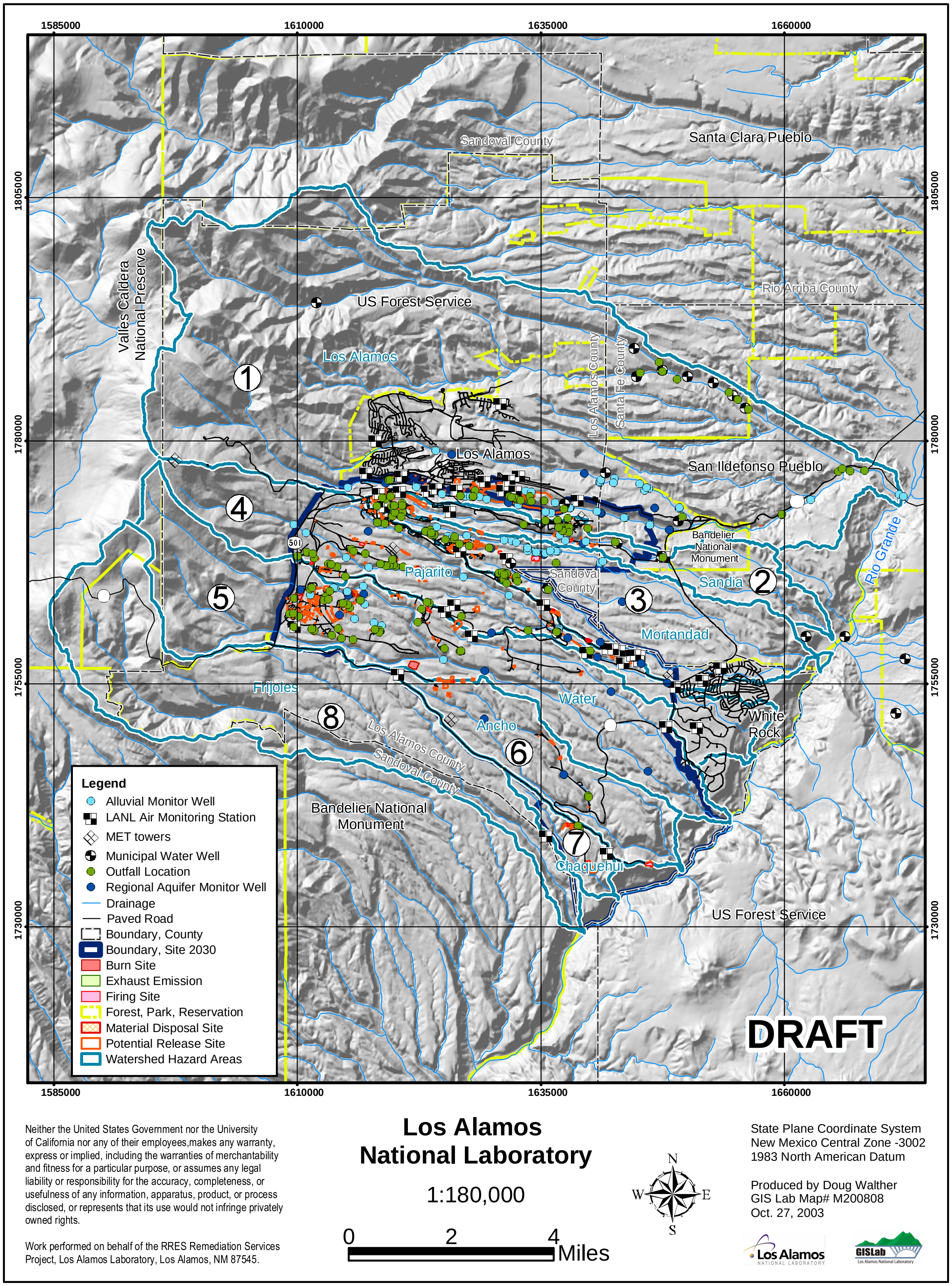


Figure 4.0b. Site-wide hazard map, End state.

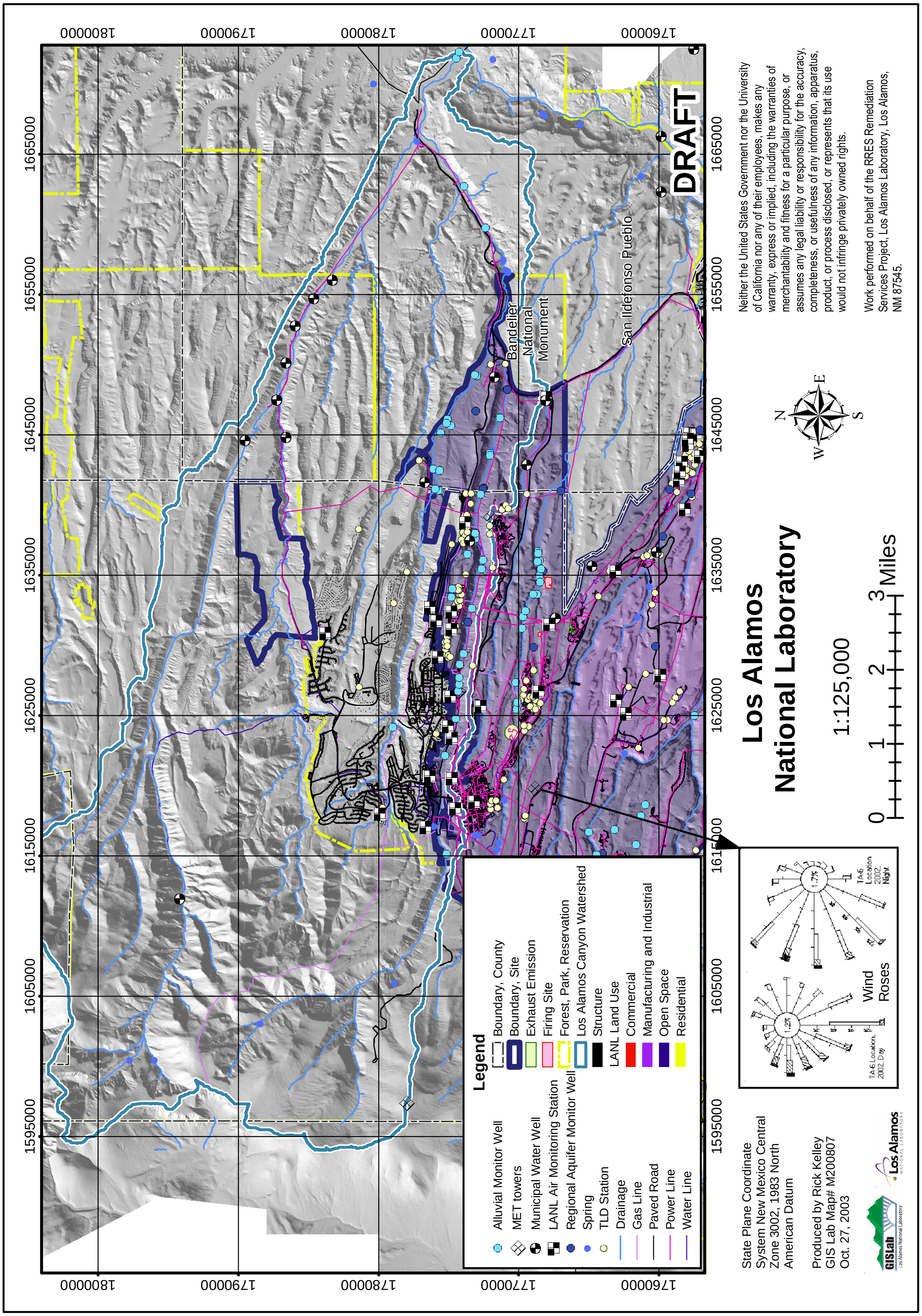
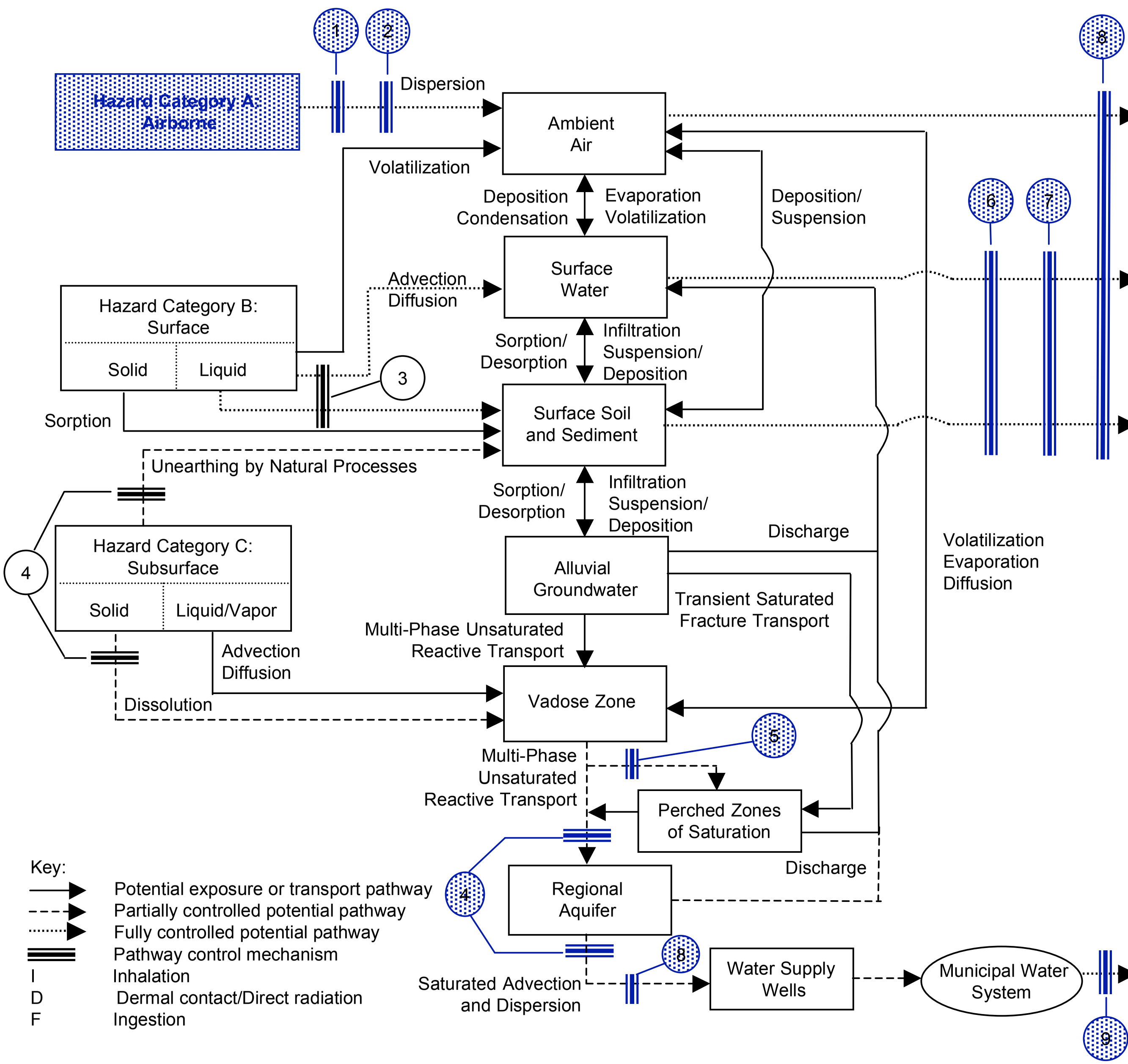


Figure 4.1a1. Hazard Area 1: Los Alamos Canyon Watershed, Hazard Category A: airborne releases, Current state.

Hazard Category A Conceptual Site Exposure Model– Current State



Potential Exposures

Occupational	Recreational Onsite	Recreational Offsite	Residential	Ecological
I/D	I/D	I/D	I/D	I/D
D/F	D/F	D/F		D/F
I/D/F	I/D/F	I/D/F	I/D/F	I/D/F
D/F			D/F	

also identifies LANL's air monitoring stations and thermoluminescent radiation detectors (TLDs). The conceptual site exposure model highlights the existing pathway controls for potential exposures to airborne contamination.

Hazard Category B represents surface legacy contamination on mesa tops, canyon slopes, and within canyons as a result of permitted operational discharges directly into portions of the watershed, and as a result of surface-water and airborne transport of contamination from legacy sources within the watershed. Figure 4.1a2 identifies the current surface contamination sources, which are dominated by outfalls from operational facilities. Potential release sites in this category are also shown, as are the environmental monitoring stations. The associated conceptual site exposure model identifies the existing controls relevant to controlling exposures to surface releases. Exposures to contaminated media under current conditions are controlled by natural processes that attenuate contaminant concentrations as a function of distance from their sources, and by institutional and administrative controls.

Characterization of contaminated surface and alluvial materials is systematically conducted in accordance with a physical geomorphology model. The Los Alamos/Pueblo watershed geomorphology model is considered representative of the range of features, events, and processes occurring in the other watersheds of the Pajarito Plateau.

Based on the geomorphology model and data collected to date, sediment transport by surface water is judged to be the predominant mechanism for redistributing contaminants into and within canyons comprising the Los Alamos/Pueblo watershed. The present inventory of contaminants in canyons is dominated by secondary contamination from legacy liquid discharge sources, which subsequently adsorbed onto relatively fine-grained sediment particles. While secondary contamination transported into canyons mainly bind to the sediments, more soluble contaminants remain in solution. Larger particles such as shrapnel dispersed from explosives testing can be transported as particles on the streambed.

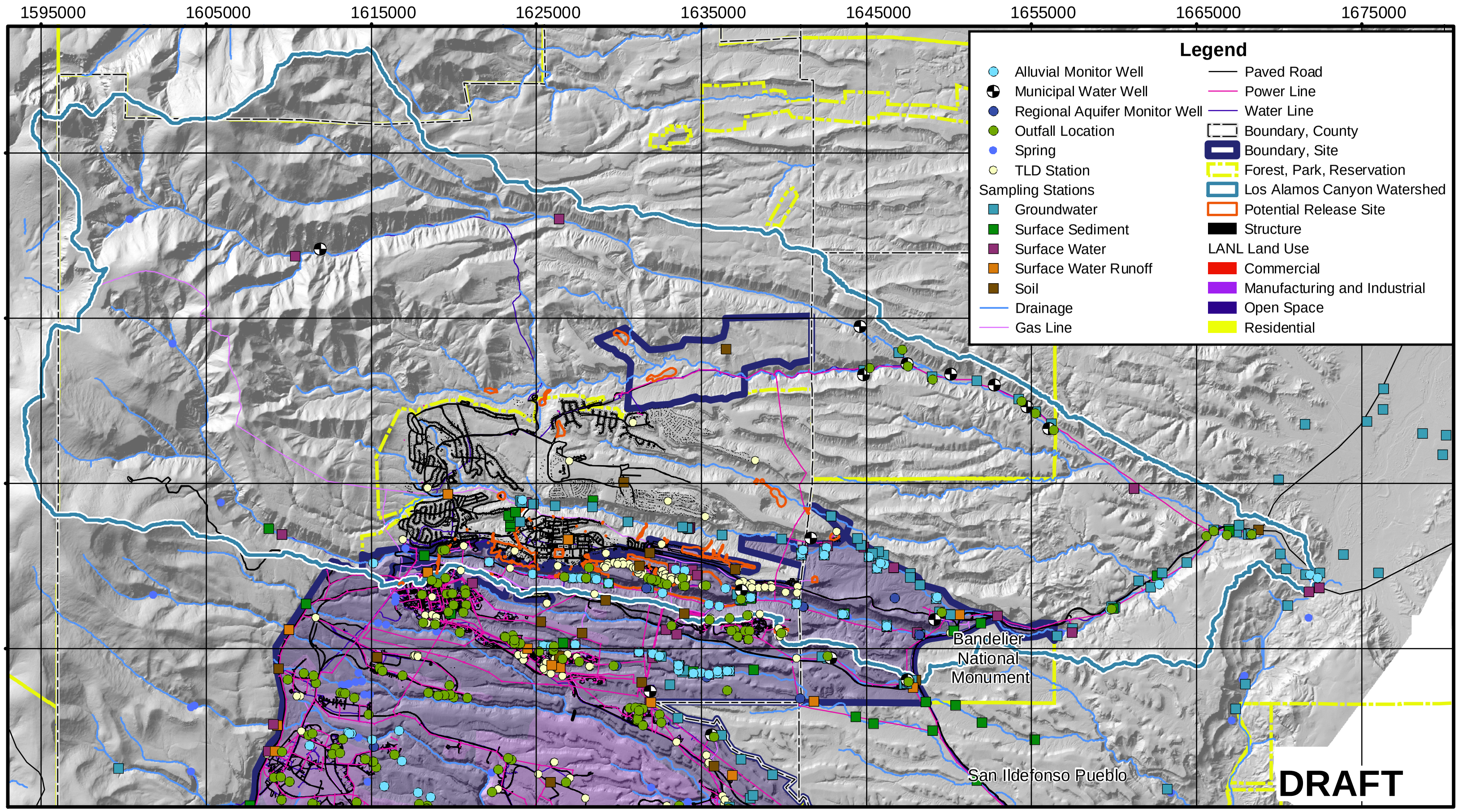
Sediment transport occurs during floods, snowmelt events, and sustained releases from outfalls. The largest floods, and therefore the largest potential for sediment redistribution, are caused by summer thunderstorms. Sediment transported by these flows is either redeposited downstream at various locations or transported to the Rio Grande. One effect of continued sediment transport over time is to decrease the total inventory of contaminants in some upstream areas and increase the inventory in some downstream areas.

Sediments and associated contaminants deposited in different geomorphic locations, such as active channels, inactive channels, and floodplains or low terraces, remain in place for varying lengths of time. Transport of sediments in active channels can occur during relatively frequent, moderate-sized storm or snowmelt flows, whereas transport of sediments currently residing in floodplains and low terraces requires infrequent large floods during which the stream channel can erode laterally. Contaminants in floodplains and low terraces may remain in storage for decades or longer.

Groundwater transport of contaminants in sediment or bedrock, under both saturated and unsaturated flow conditions, is considered a potential transport pathway in the Los Alamos/Pueblo watershed. Groundwater in unsaturated zones is considered to be a transport pathway between saturated zones, not an exposure pathway. Water in these zones is not sufficient in either quantity or continuity to provide a reliable drinking water source for humans.

Contaminants will migrate laterally down the canyon through the alluvium in interaction with the surface water. Groundwater from the alluvium may be an important source of recharge for intermediate perched zones. Relatively rapid infiltration may be occurring beneath the alluvium in the downstream reaches of Los Alamos/Pueblo watershed by unsaturated flow through the porous matrix of the Otowi Member of the Bandelier Tuff. Hydraulic interconnections between the alluvium and the intermediate perched zones are evidenced in Los Alamos/Pueblo watershed. There is also evidence of recharge between the alluvium and the regional aquifer in lower Los Alamos/Pueblo watershed, where the canyons cut into the Otowi Member of the Bandelier Tuff.

Groundwater in the alluvium has historically had the highest concentrations of contaminants of any groundwaters in the area. Groundwater within the intermediate perched zones generally contains lower concentrations of the known contaminants. Groundwater in the regional aquifer generally appears to be uncontaminated.



State Plane Coordinate
System New Mexico Central
Zone 3002, 1983 North
American Datum

Produced by Rick Kelley
GIS Lab Map# M200846
Oct. 28, 2003

GISLab
Los Alamos

N
W E
S

Los Alamos
National Laboratory

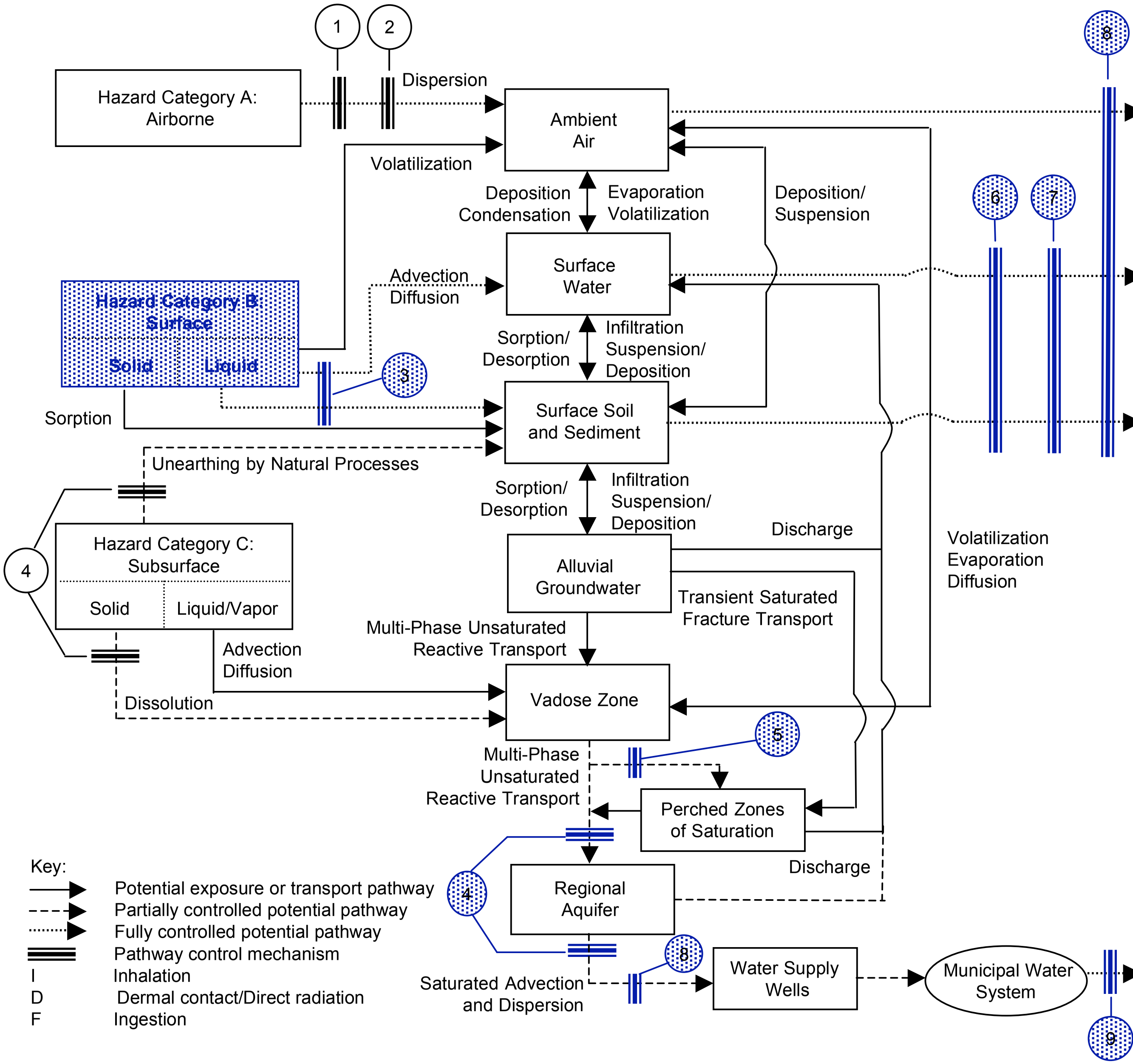
1:125,000

0 1 2 3 Miles

Work performed on behalf of the RRES Remediation Services Project, Los Alamos Laboratory, Los Alamos, NM 87545.

Figure 4.1a2. Hazard Area 1: Los Alamos Canyon Watershed, Hazard Category B: surface releases, Current state.

Hazard Category B Conceptual Site Exposure Model– Current State



Potential Exposures

Occupational	Recreational Onsite	Recreational Offsite	Residential	Ecological
I/D	I/D	I/D	I/D	I/D
D/F	D/F	D/F		D/F
I/D/F	I/D/F	I/D/F	I/D/F	I/D/F
D/F			D/F	

Hazard Category C represents primary sources of contamination in the subsurface. In the Los Alamos/Pueblo watershed, there are five MDAs within Hazard Category C. All five are located on the mesa where the most intensive nuclear materials processing operations were conducted into the 1970s. With the exception of MDA B, all of the MDAs are located near facilities that are still used by LANL, where perimeter fencing controls access. Radiological hazards signs are posted where the MDAs are located. MDA B is located across the street from a light industrial/commercial section of the town of Los Alamos, and is adjacent to a parking lot. MDA B is surrounded by a fence and posted to prevent access. The MDAs are capped with native materials (crushed tuff) and vegetation (primarily grasses).

Figure 4.1a3 identifies the MDAs comprising Hazard Category C in the Los Alamos/Pueblo watershed, along with other contextual features related to the control of potential exposures to these hazards. The associated conceptual site exposure model identifies the existing natural, engineered and institutional controls that control exposures to hazards MDAs. The following paragraphs summarize the current state of each MDA, and provide information relevant to the controls included in the conceptual site exposure model.

MDA A

MDA A was used for waste disposal during two periods, 1945-1949 and 1969-1977. Between 1944 and 1947, two shallow pits approximately 4 m (13 ft) deep received about 1020 m3 (36,000 ft3) of “solid wastes with alpha contamination accompanied by small amounts of beta and gamma.” (Rogers 1977, 0216) During this period, two underground storage tanks (the General’s Tanks) were installed to store a total of 49,000 gal. (186,200 l) of a sodium hydroxide solution, which contained 334 g (0.7 lb.) of plutonium-239 at the time of emplacement (circa 1947). The liquid from these tanks was recovered, treated, and solidified in cement in 1975. The contaminated cement remained buried at MDA A for several years, but was retrieved in the late 1980s and moved to MDA G. In 1969, a 9-m- (30-ft-) deep pit was excavated at MDA A for the disposal of building debris contaminated by uranium-235, plutonium-238, and plutonium-239 from nearby demolition work.

MDA B

MDA B was active from 1945 through 1948. A geophysical survey conducted in 1998 identified two disposal trenches approximately 15 ft (4.5 m) wide by 300 ft (90 m) long by 12 ft (3.6 m) deep and unlined, containing roughly 21,240 m3 (27,612 yd3) of waste. The radiological inventory includes “plutonium, polonium, uranium, americium, curium, lanthanum, (and) actinium.” (Rogers 1977, 0216) The disposal capacity of the pits is estimated to be about 21,000 m3 (760,000 ft3). The entire pit area is estimated to contain no more than 100 g (6.13 Ci) of plutonium-239. In 1984, portions of MDA B were resurfaced with a variety of cover systems as a pilot study conducted for DOE. These applications are still in place, all having about 3-ft- (1 m) crushed-tuff cover, which is placed over the original crushed-tuff cover. Variations include cobble and gravel biological barriers between the old and new covers, as well as shrub, grass, and gravel/mulch surface treatments. The total cover of this portion of MDA B is nominally 6.5-ft- (2 m) thick.

MDA T

MDA T received radioactively contaminated liquid from the plutonium processing laboratories between 1945 and 1952. In 1952, a liquid waste treatment plant was installed to remove plutonium and other radionuclides from process wastewater. Thereafter, the absorption beds received relatively small quantities of liquid waste until 1967, when a new liquid waste treatment process was initiated. Between 1968 and 1975, treated liquid waste was mixed with cement that was pumped into shafts at MDA T for disposal. After 1975, the cement paste was poured into corrugated metal pipes prior to emplacement in the subsurface, and retrievably placed at MDA T in 62 vertical shafts. Approximately 18,300,000 gallons (69,540,000 l) of liquid waste was discharged to the MDA T absorption beds between 1945 and 1967. “As of January 1973, the absorption beds contained . . .10 Ci of plutonium-239. . . As of July 1976, the disposal shafts contained 7 Ci of uranium-233, 47 Ci of plutonium-238, 3,761 Ci of americium-241, and 3 Ci of mixed fission products.” (Rogers 1977, 0216) The total volume of cement paste permanently disposed in shafts at MDA T was 122,500 ft^3 (36,750 m^3).

MDA U

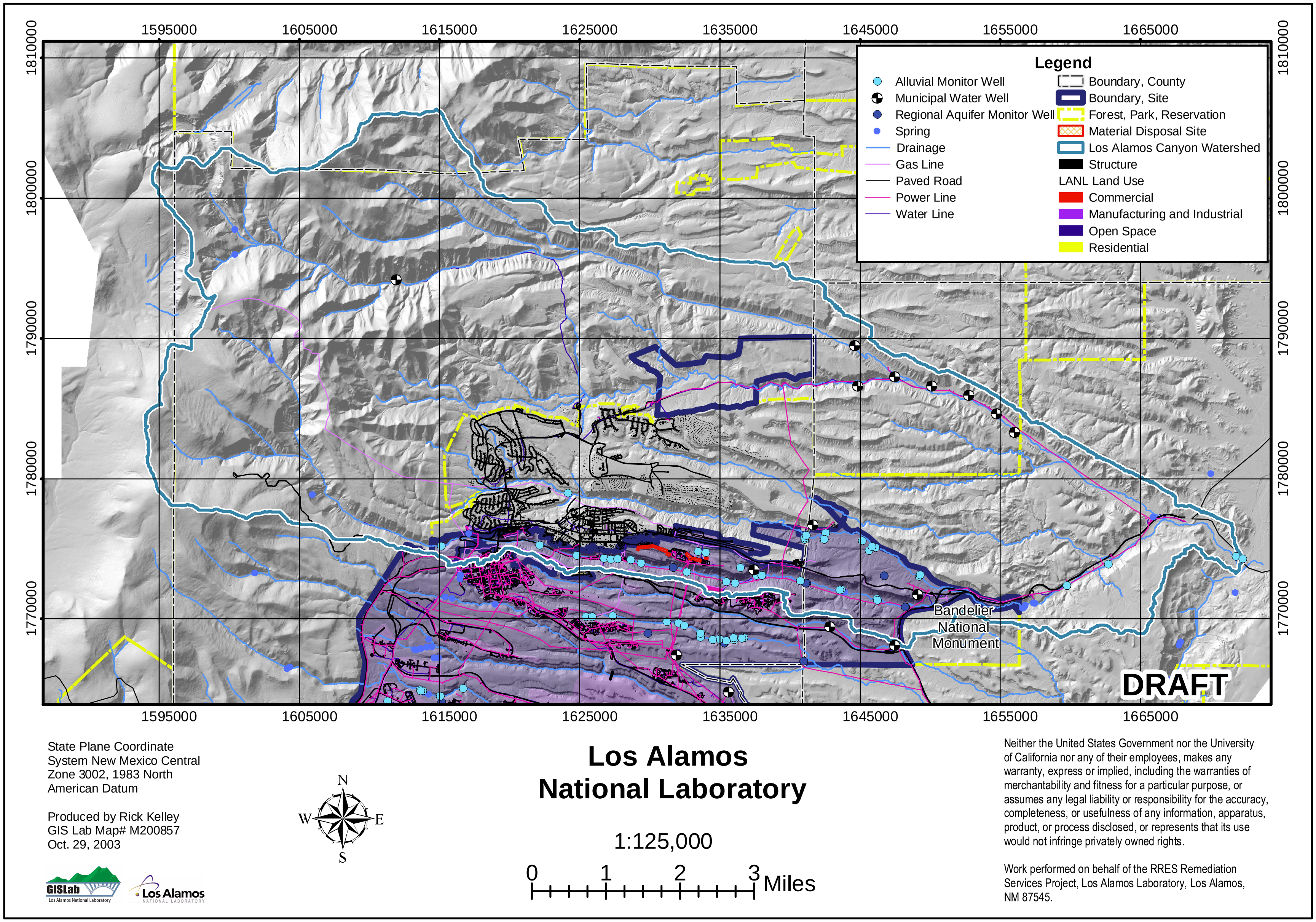
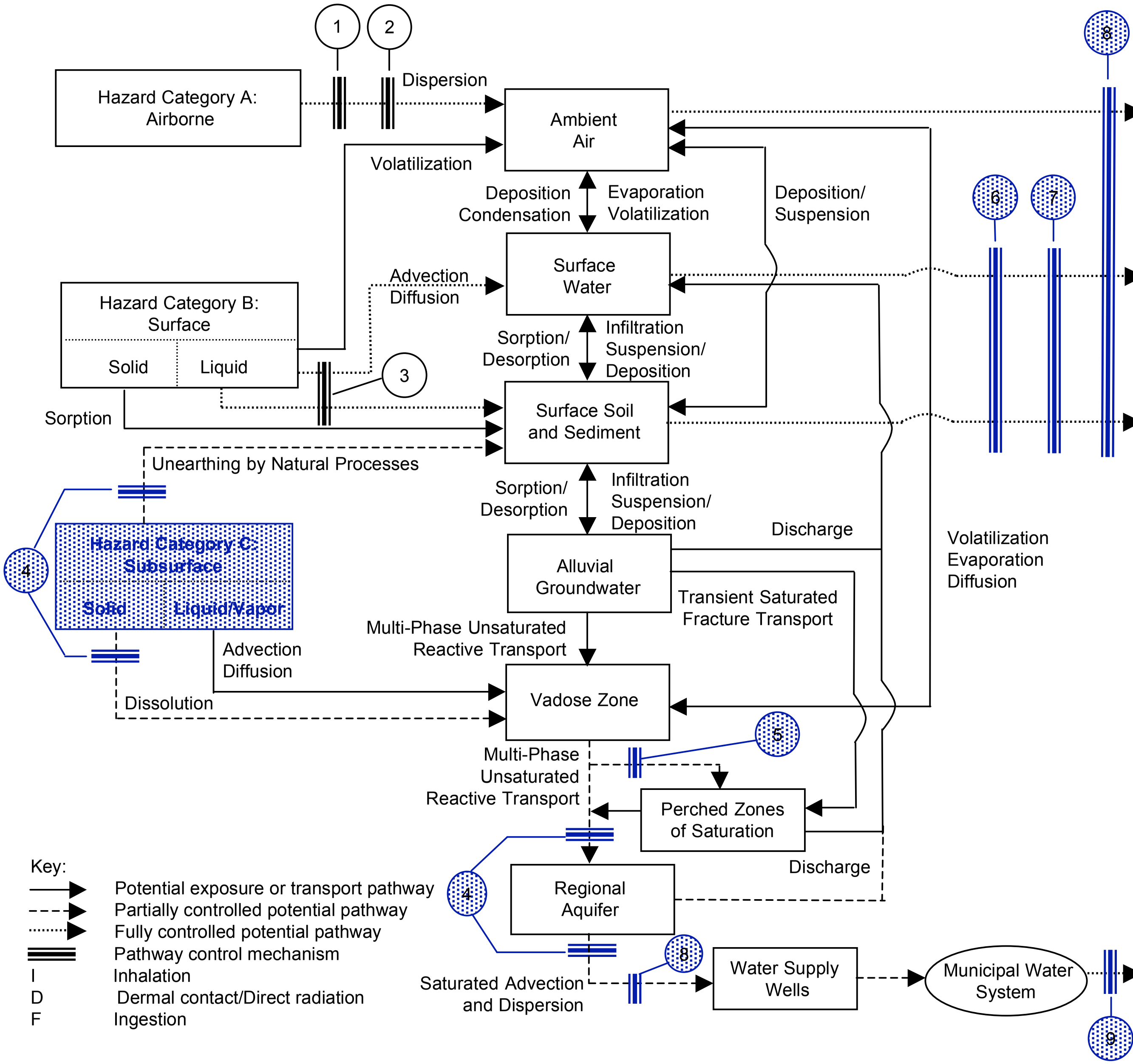


Figure 4.1a3. Hazard Area 1: Los Alamos Canyon Watershed, Hazard Category C: subsurface releases, Current state.

Hazard Category C Conceptual Site Exposure Model– Current State



Potential Exposures

Occupational	Recreational Onsite	Recreational Offsite	Residential	Ecological
I/D	I/D	I/D	I/D	I/D
D/F	D/F	D/F		D/F
I/D/F	I/D/F	I/D/F	I/D/F	I/D/F
D/F			D/F	

MDA U absorption beds have a surface area of approximately 1800 ft^2 (162 m^2) and an estimated volume of about 18,000 ft^3 (540 m^3). They were used for subsurface disposal of radioactively contaminated liquid wastes from 1948 to 1968 (LANL 1991, 7529). The distribution box liquid-waste distribution systems were removed in 1985. Remaining is subsurface contamination bound to solid phases, covered by crushed tuff and native grasses. MDA U is fenced and posted as a radiological hazard.

MDA V

MDA V absorption beds occupy 15,000 ft^2 and have a volume of 4250 m^3 (5525 yd^3), used from 1945 through 1961 for liquid waste disposal from a laundry facility at TA-21-20. The laundry facility mainly washed clothing from uranium and plutonium refinement operations. A portion of MDA V was used recently for a successful demonstration of non-traditional in situ vitrification. The remainder of the site is covered with a vegetated crushed tuff cover.

The records of disposals summarized above were sufficient to provide bounding inventory estimates for radionuclides for the purposes of the MDA G composite analysis, which calculated the cumulative impacts of these MDAs at offsite receptor points defined in the MDA G performance assessment. The results of the composite analysis provides a first-order indication that multiphase unsaturated reactive transport processes naturally attenuate the groundwater-pathway risks posed by the hazards in MDAs A, B, C, T, U, and V.

Several studies of radionuclide transport beneath MDA T were conducted before the cleanup project was initiated. As a group, these studies indicate that radionuclides in liquid waste discharged directly into the Bandelier Tuff migrated to depths of hundreds of feet within the mesa, and also contaminated surface media. These results have not been refuted by investigations conducted in support of the cleanup project. Generalizing these results to MDAs U and V, which also received liquid waste, exposures are limited to direct contact with surface contamination. Such exposures are controlled by access restrictions and postings for radiological hazards.

4.1.2 Risk-Based End State

Figure 4.1b1 includes the anticipated risk-based end state to be achieved by remedial actions and institutional controls through 2035. Due to the small number of cleanup sites in Hazard Category A, and since LANL operations are not expected to change dramatically, few changes are visible on this map format. The conceptual site exposure model provides additional detail on the controls that are anticipated to achieve and maintain the risk-based end state relative to airborne releases.

Similar maps and associated conceptual site models are provided for the surface releases in Figure 4.1b2 and 4.1b3. The end states represented on these maps were discussed in Section 3. Risk-based decision analysis methods will be used to define cleanup goals for surface contamination and cap designs for MDAs. Cleanup goals will be consistent with industrial-use scenarios for locations within the LANL boundary identified as industrial use, and with recreational use scenarios for many of the canyons to be retained by LANL. Residential use scenarios will be used to support decisions for land tracts that may be transferred. The cap designs for the MDAs will be based on industrial-use scenarios, consistent with the planned land use. Monitoring of surface water and groundwater will also be based on risk-based decision analysis.

4.2 Hazard Area 2 – Sandia Watershed

The Sandia watershed heads on the plateau within the Laboratory boundary. It has a total drainage area of about 5.5 mi^2. The small drainage extends for about 10 mi across the central part of the LANL, and crosses San Ildefonso Pueblo land for about 3 mi before joining the Rio Grande.

The Sandia watershed is ephemeral to a point about 3 mi east of LANL's eastern boundary, where Sandia Spring supports perennial flow for a few hundred yards. This flow does not normally reach the Rio Grande. In the upper canyon, an effluent-supported reach arising from discharge of treated sanitary effluent supports a significant wetland and typically extends about 2.5 to 3 mi before infiltrating into the canyon bottom alluvium.

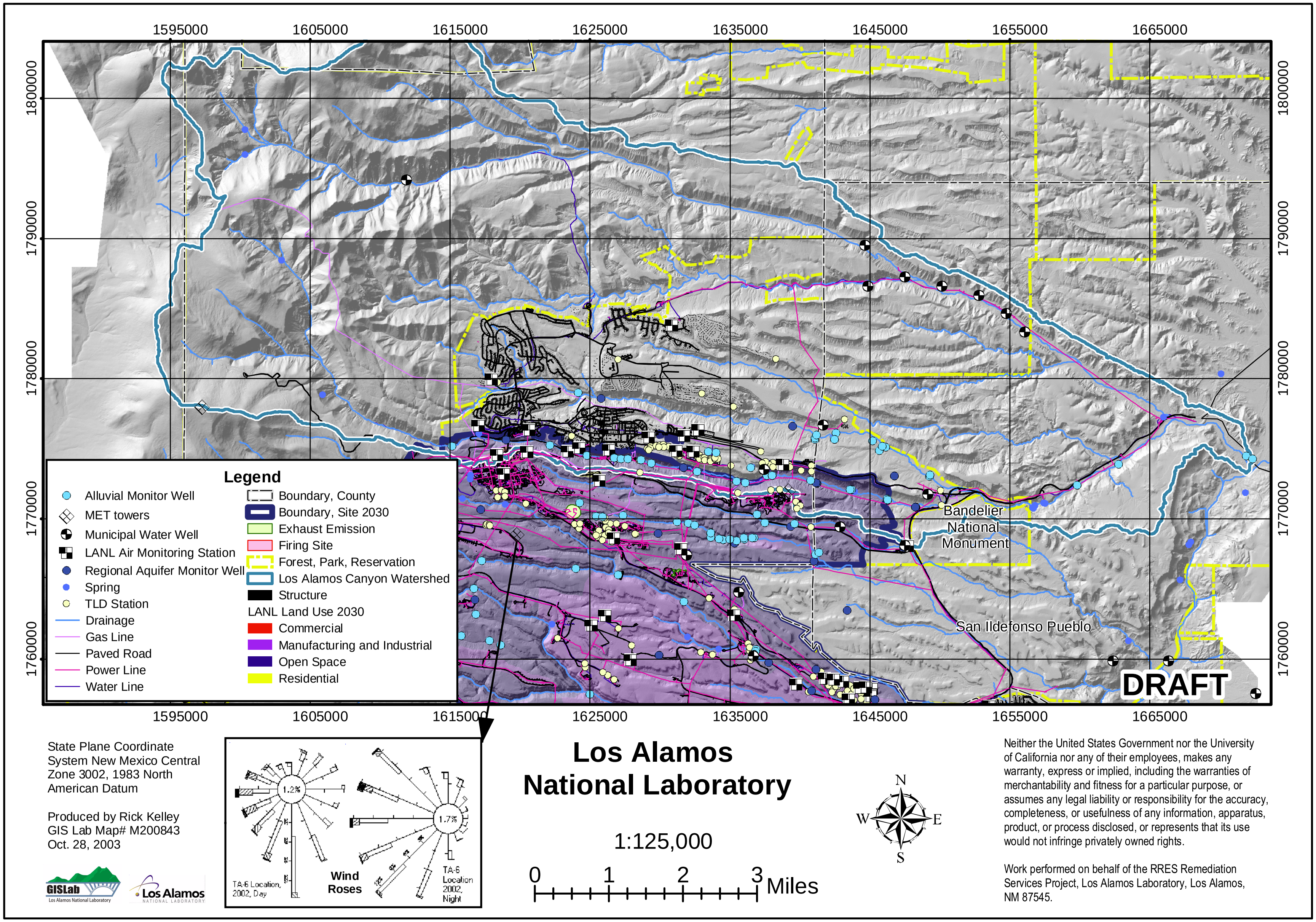


Figure 4.1b1. Hazard Area 1: Los Alamos Canyon Watershed, Hazard Category A: airborne releases, End state.

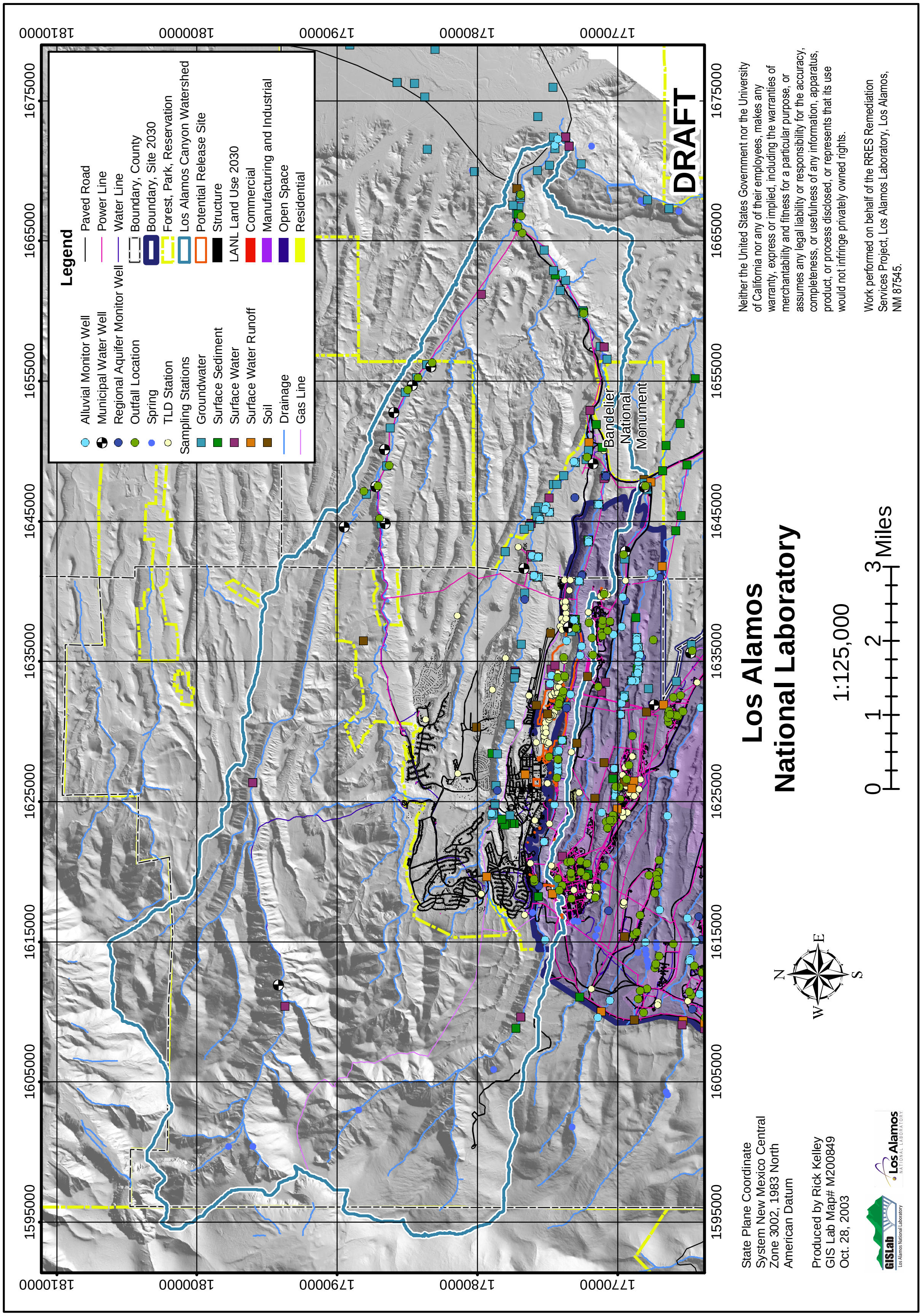


Figure 4.1b2. Hazard Area 1: Los Alamos Canyon Watershed, Hazard Category B: surface releases, End state.

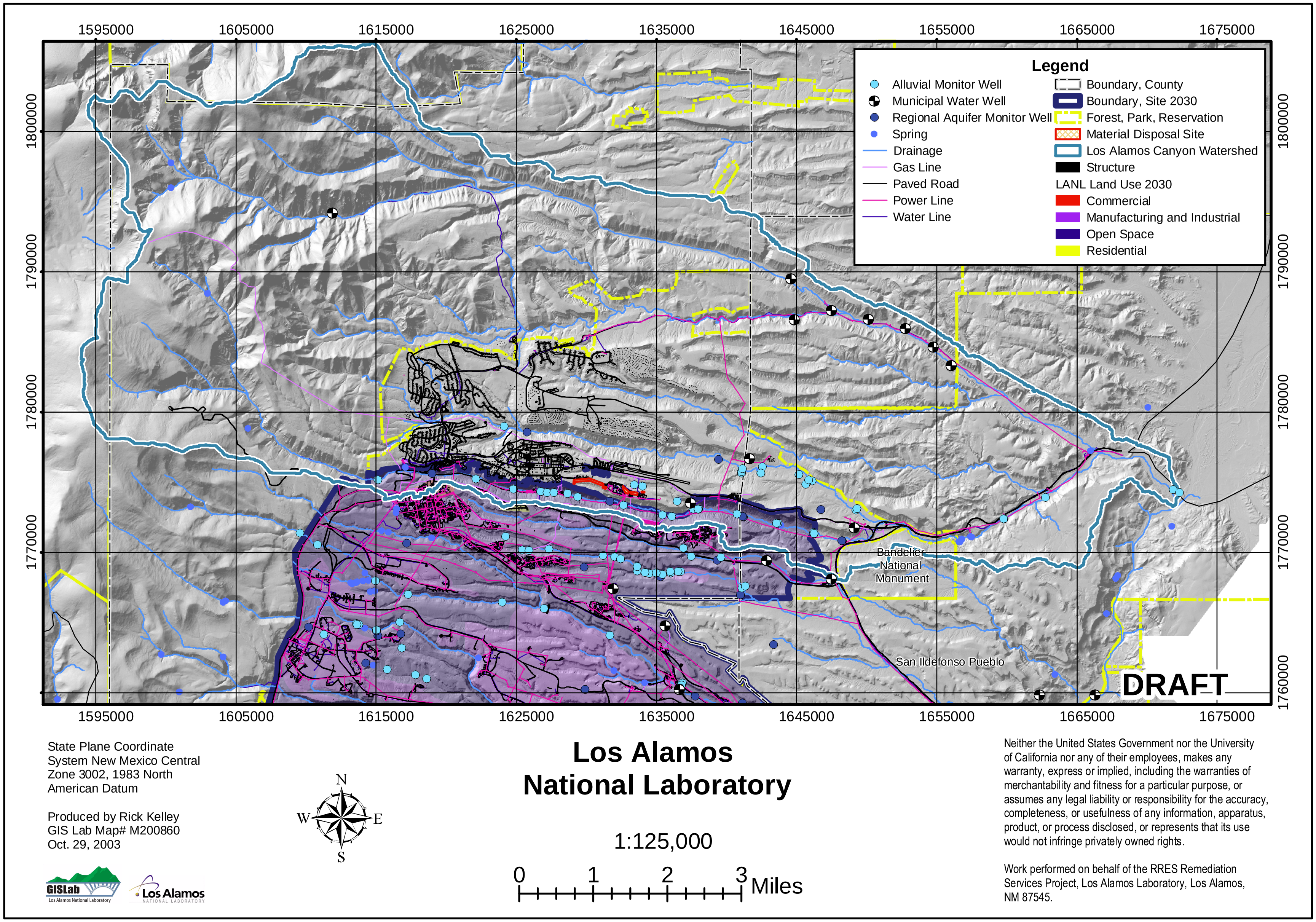


Figure 4.1b3. Hazard Area 1: Los Alamos Canyon Watershed, Hazard Category C: subsurface releases, End state.

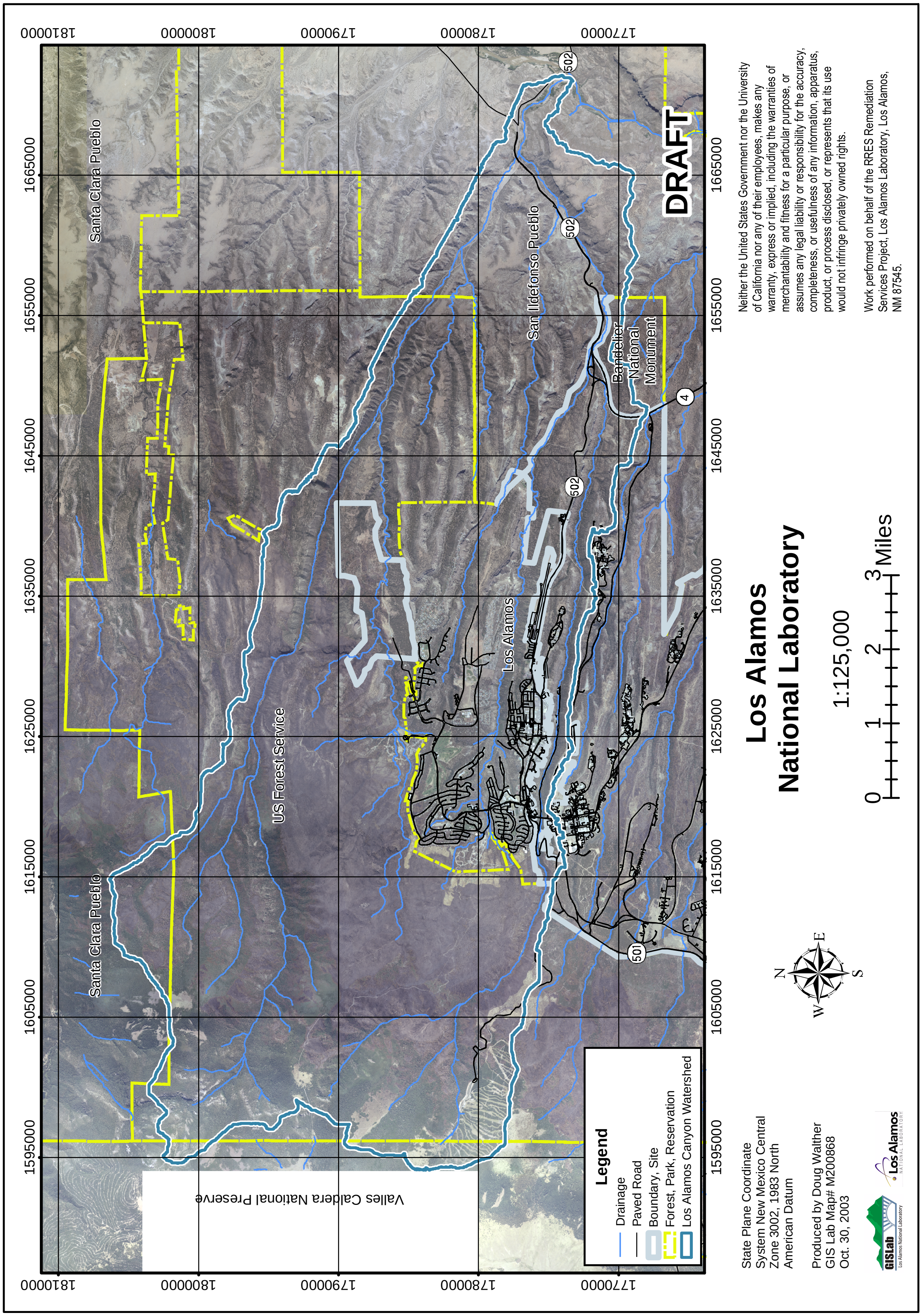
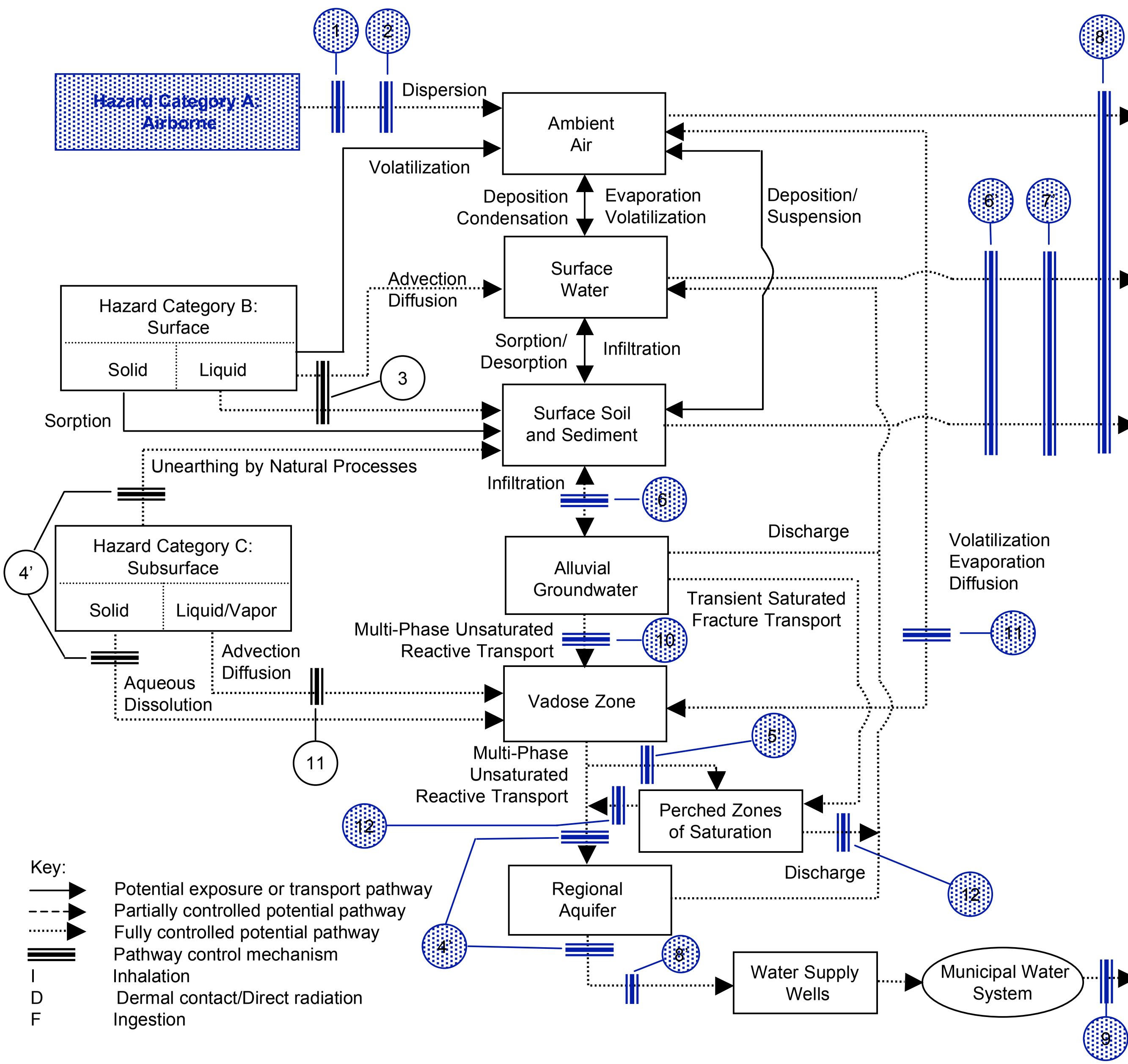


Figure 4.1a4. Hazard Area 1: Los Alamos Canyon Watershed orthophoto map.

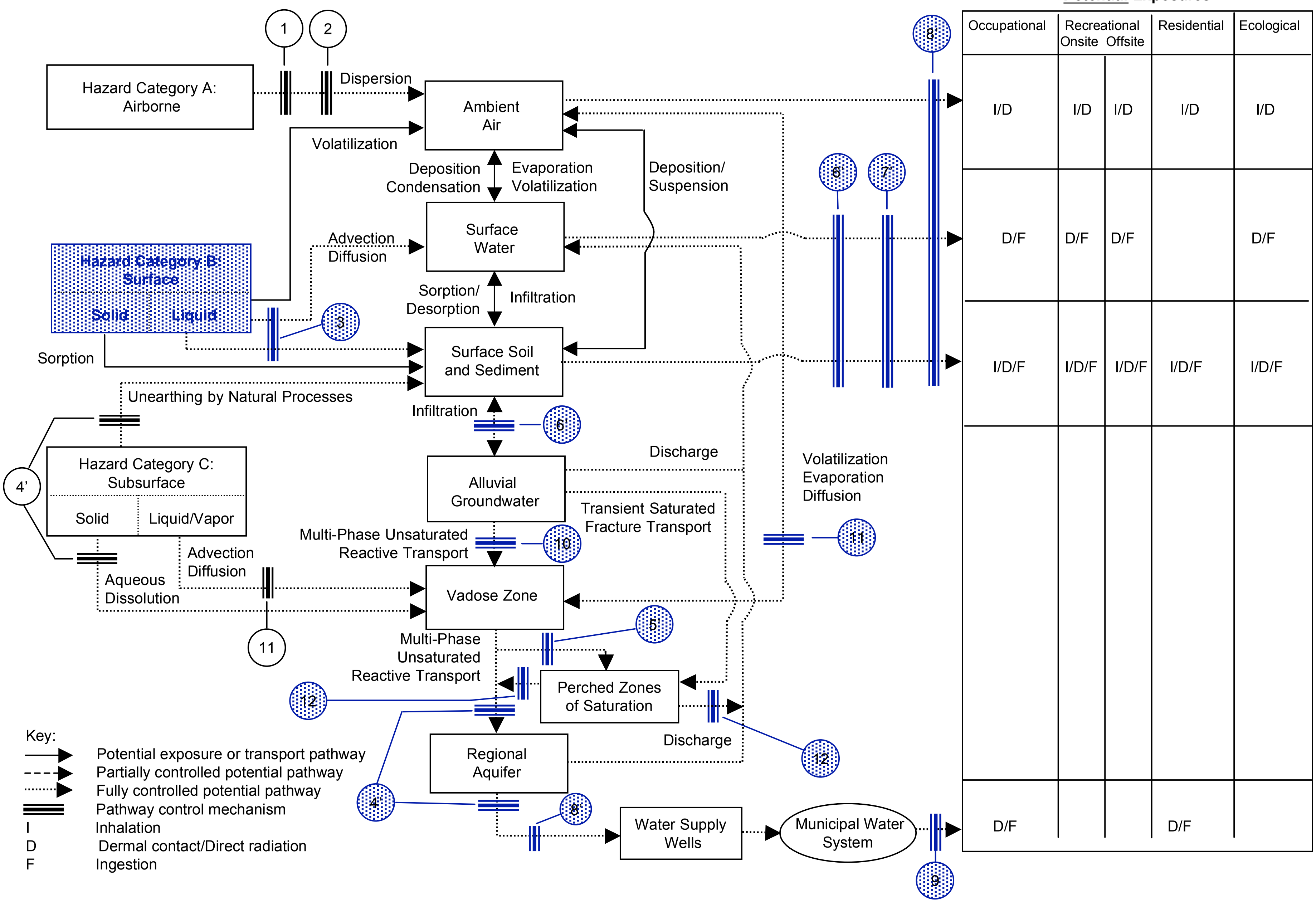
Hazard Category A Conceptual Site Exposure Model– End State



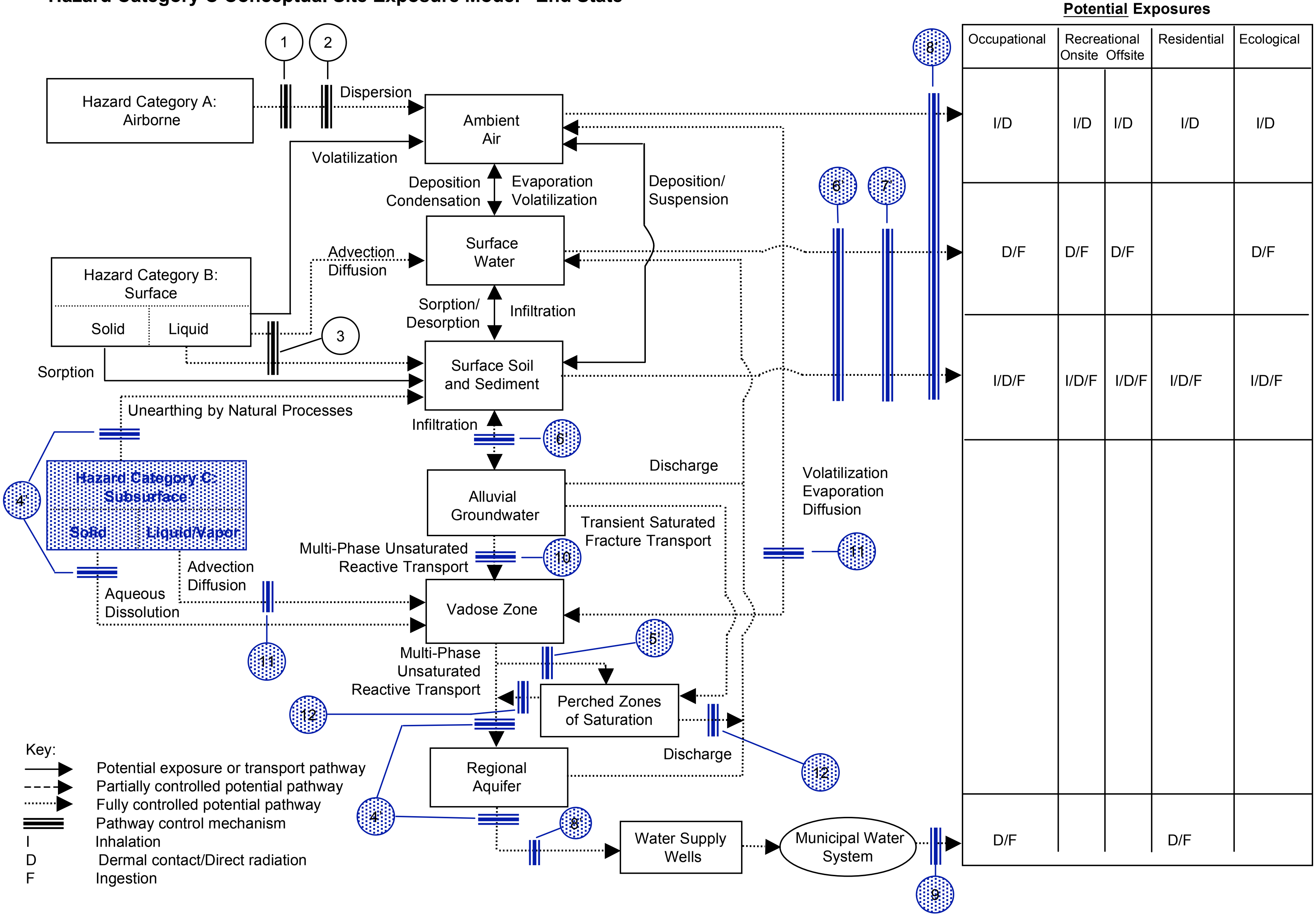
Potential Exposures

Occupational	Recreational Onsite	Recreational Offsite	Residential	Ecological
I/D	I/D	I/D	I/D	I/D
D/F	D/F	D/F		D/F
I/D/F	I/D/F	I/D/F	I/D/F	I/D/F
D/F			D/F	

Hazard Category B Conceptual Site Exposure Model– End State



Hazard Category C Conceptual Site Exposure Model– End State



During the early years of LANL operations, land within the Sandia watershed was used to test neutron initiators and other types of implosion tests. Though there have been few official LANL activities in the Sandia watershed since 1948, it has been potentially impacted by outfalls and run-off from mesa-top activities.

4.2.1 Current State

As Figure 4.2a1 shows, there are no existing airborne discharges (Hazard Category A) within the Sandia watershed.

Figure 4.2a2 shows a number of existing surface sources within Sandia watershed, primarily associated with liquid discharges from operating facilities. The existing pathway controls are identified in the accompanying conceptual site exposure model for surface releases under current conditions.

As seen in Figure 4.2a3, there are no subsurface sources of contamination in the Sandia watershed.

4.2.2 Risk-Based End State

The risk-based end-state analogs of the current-state hazard-specific maps for the Sandia watershed are shown in Figures 4.2b1, 4.2b2, and 4.2b3, for anticipated airborne, surface, and subsurface contaminant sources in 2035. Since surface contamination is the only significant hazard in this watershed, the end state reflects cleanup to industrial-use and/or recreational-use levels for lands that will be retained by LANL in 2035. The associated end-state conceptual site exposure model for Hazard Category B in Sandia watershed is attached to Figure 4.2b2.

4.3 Hazard Area 3 – Mortandad Watershed

The Mortandad watershed is an east to southeast trending canyon that heads on the Pajarito Plateau near the main LANL complex at an elevation of 7380 ft asl. The drainage extends about 15 mi from the headwaters to its confluence with the Rio Grande at an elevation of 5440 ft asl, draining an area of about 9 mi^2. The canyon crosses San Ildefonso Pueblo land for several miles before joining the Rio Grande. The canyon passes through or is adjacent to several of LANL's main operational sites.

The watershed canyon is cut into the Tshirege Member of the Bandelier Tuff, with steep walls that are near vertical in some places. The canyon floor is narrow from the head and widens eastward. The stream channel is entrenched in the wider portion of the canyon.

The streamflow in the upper portions of the Mortandad watershed is ephemeral with no known springs. Treated effluent from the Los Alamos County White Rock Sewage Treatment Plant enters they canyon near the LANL boundary and generally flows to the Rio Grande.

Secondary liquid and sludge wastes have been discharged into different sections of the Mortandad watershed from two of LANL's central wastewater treatment plants. One of the plants operated between 1951 and 1963, and the other since 1963. The current discharges are permitted and monitored consistent with the Clean Water Act.

The central reach of the Mortandad watershed is bordered on the south by a mesa where several major core-mission facilities are located. There are many legacy-waste sites associated with former operations at these facilities. The contamination potentially transported from mesas into the watershed is judged to be insignificant relative to the impacts associated with former treated wastewater discharges.

Surface-water flow and alluvial groundwater in the Mortandad watershed is heavily monitored downgradient from the discharge locations. The effluent from the operating liquid-waste treatment facility exceeded the DOE DCGs for radionuclides six times from 1993 to 1995: for americium-241 in 1993; for americium-241 and plutonium-238 in 1994; and for plutonium-238, plutonium-239, 240, and americium-241 in 1995 (Environmental Protection Group 1996). In addition, the effluent has exceeded the New Mexico groundwater standard for nitrate in 1993, 1994, and 1995 (Environmental Protection Group 1996).

An indication of the magnitude of contaminant transport in surface water comes from sampling and analysis in the sediment traps, which are surface berms installed to slow surface water and deposit entrained sediments before crossing the LANL boundary. In the summer of 1991, severe thunderstorms

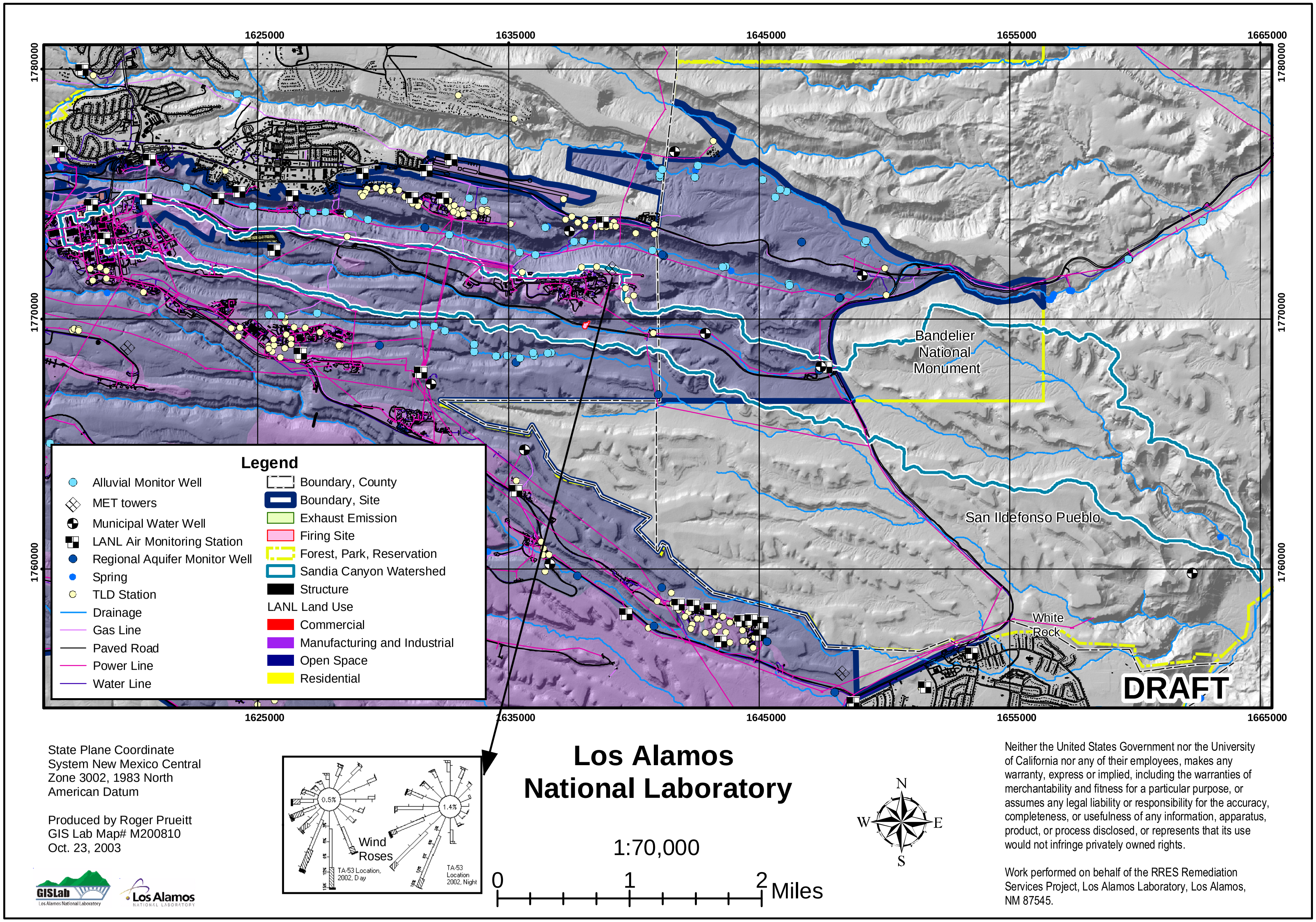


Figure 4.2a1. Hazard Area 2: Sandia Canyon Watershed, Hazard Category A: airborne releases, Current state.

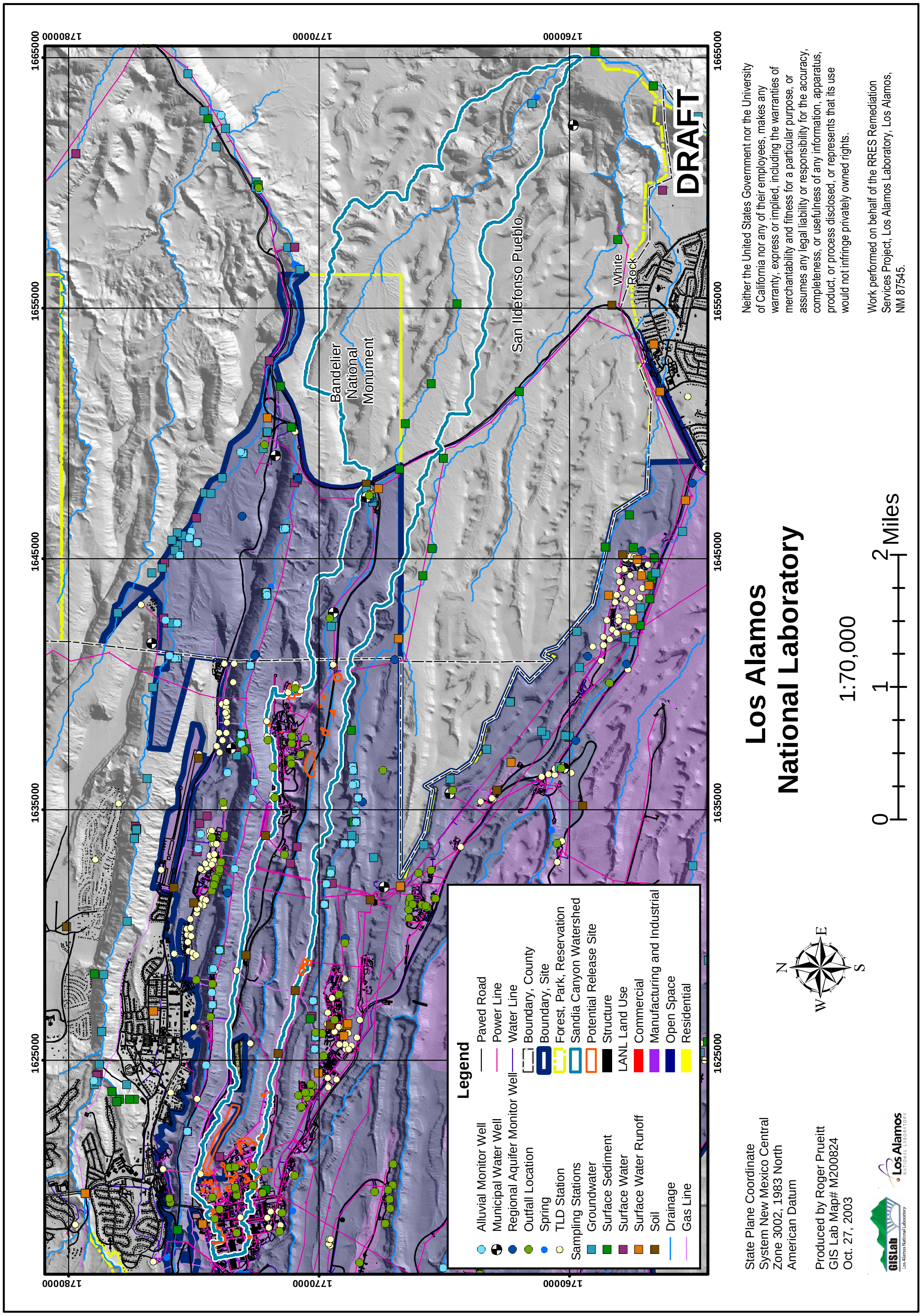


Figure 4.2a2. Hazard Area 2: Sandia Canyon Watershed, Hazard Category B: surface releases, Current state.

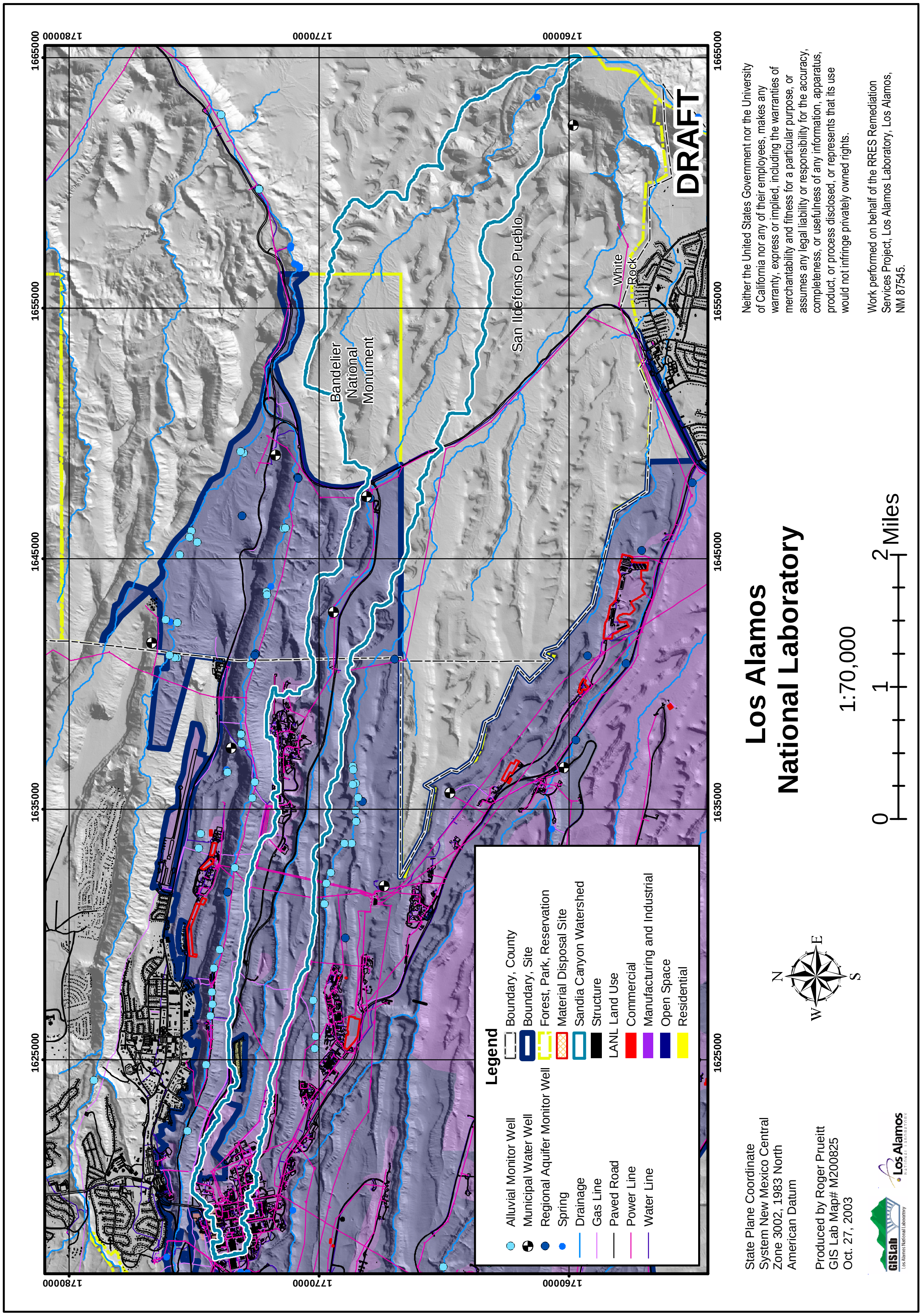


Figure 4.2a3. Hazard Area 2: Sandia Canyon Watershed, Hazard Category C: subsurface releases, Current state.

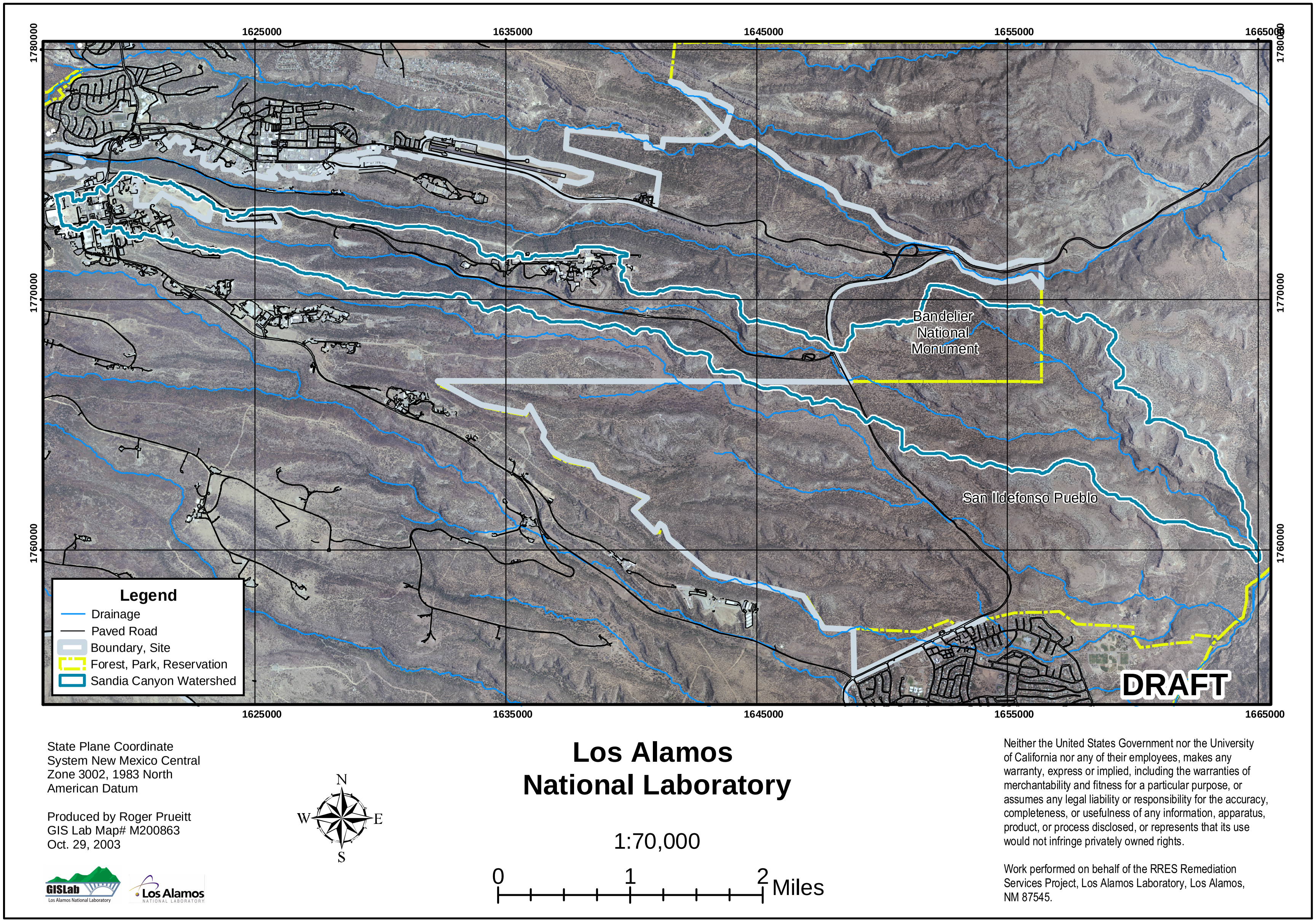


Figure 4.2a4. Hazard Area 2: Sandia Canyon Watershed orthophoto map.

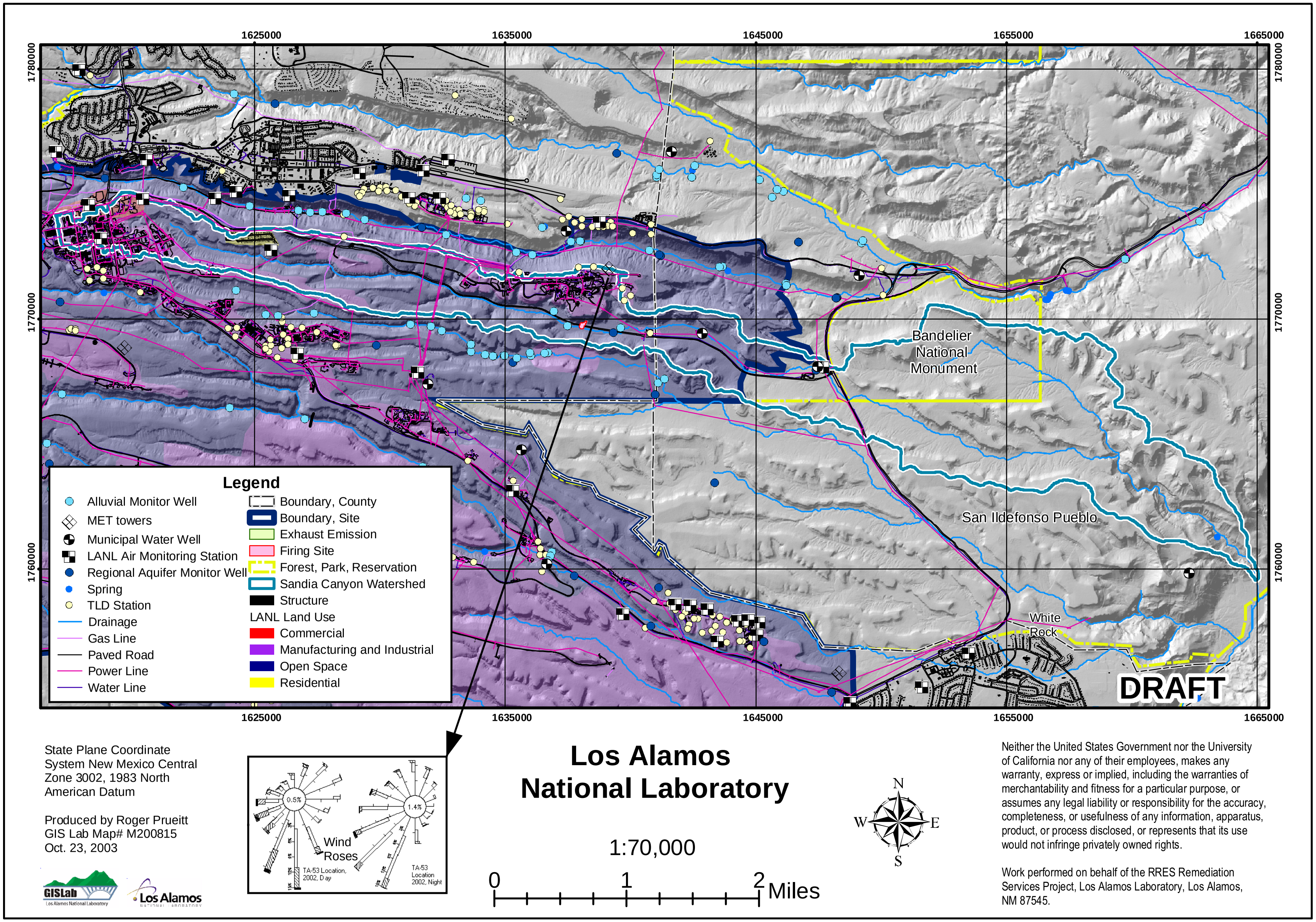


Figure 4.2b1. Hazard Area 2: Sandia Canyon Watershed, Hazard Category A: airborne releases, End state.

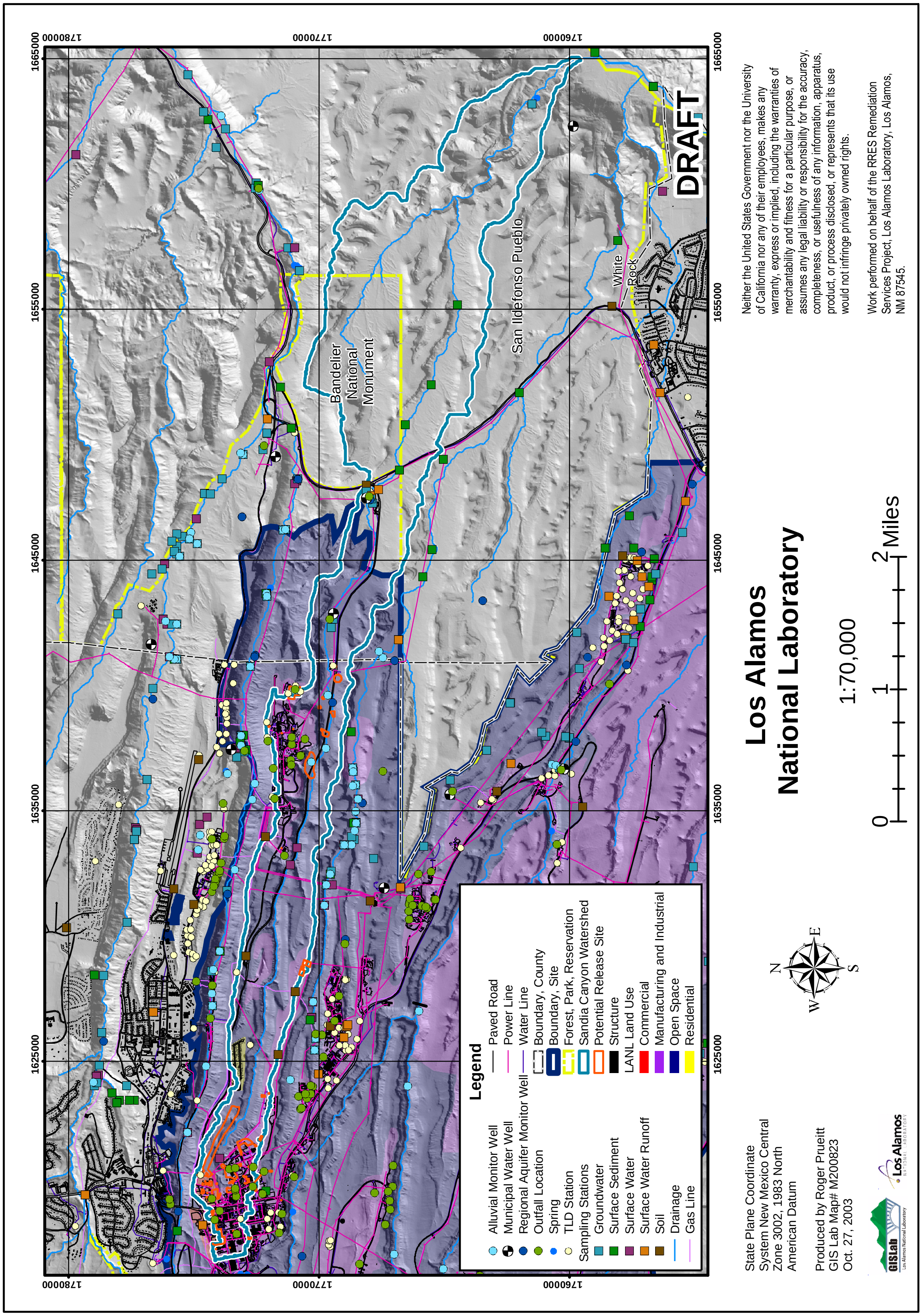


Figure 4.2b2. Hazard Area 2: Sandia Canyon Watershed, Hazard Category B: surface releases, End state.

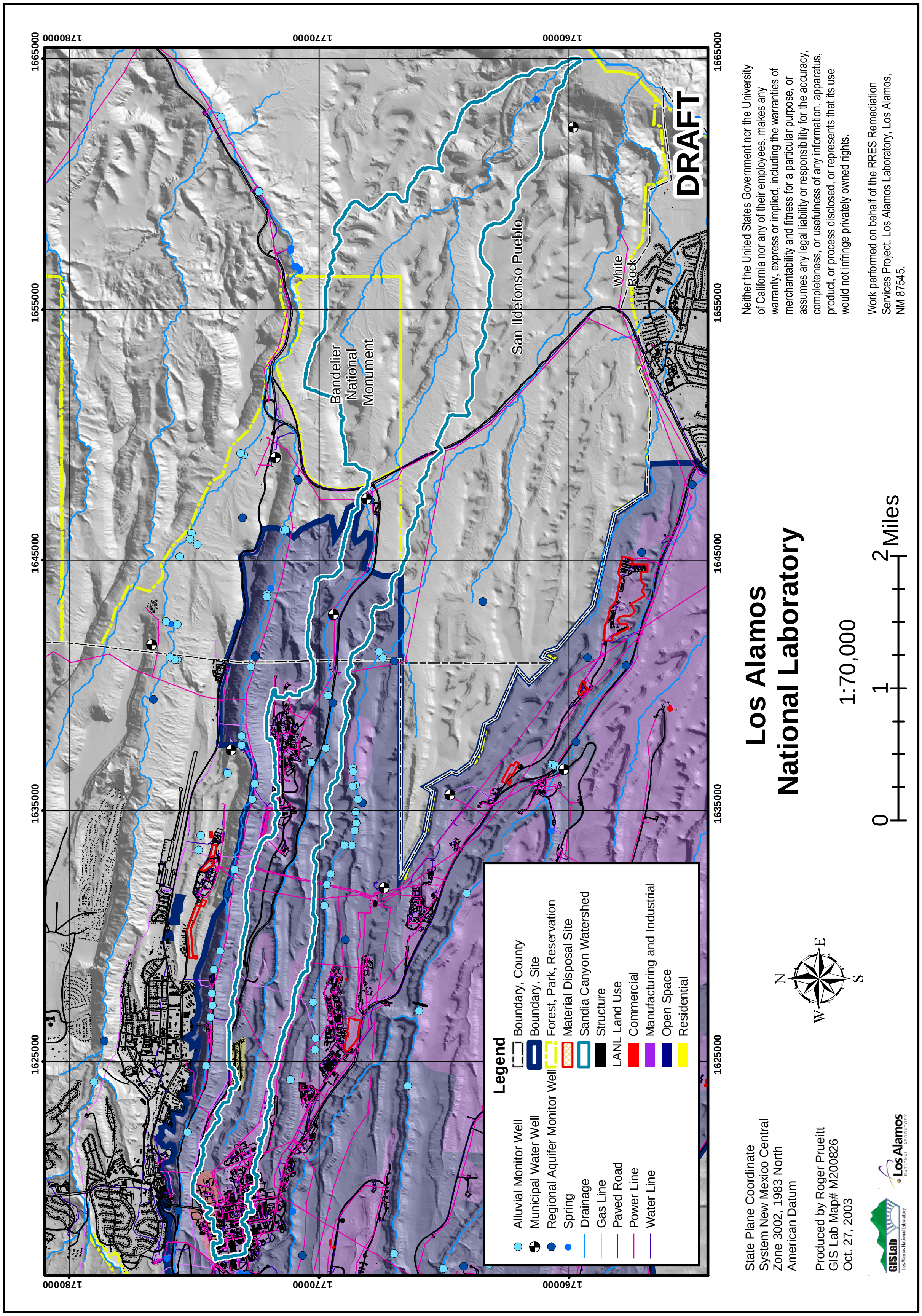


Figure 4.2b3. Hazard Area 2: Sandia Canyon Watershed, Hazard Category C: subsurface releases, End state.

filled the sediment traps with water. Samples of standing water in each of the traps were collected and filtered. The filtered water and the filters containing suspended sediments were analyzed separately (LANL 1997). The suspended sediment and water samples were analyzed for plutonium-238 and plutonium 239,240. The plutonium in suspended sediment was 10,000 to 100,000 times higher than in the water, but comparable to the plutonium content of sediments at other locations downstream of the liquid-waste outfall (LANL 1997).

Further studies on contaminant transport in the drainage indicate that plutonium and uranium in alluvial water and sediment decrease over a short distance from outfall sources. Nevertheless, data also indicate that there has been limited transport of plutonium in stream sediments across the LANL boundary.

4.3.1 Current State

Figure 4.3a1 shows the existing airborne sources of contamination in the Mortandad watershed. One is a firing site, and another is a building exhaust emission. The figure identifies the air monitoring stations and thermoluminescent radiation detectors (TLDs) that provide information needed to control exposures. The associated conceptual site exposure model identifies the pathway controls that are active for Hazard Category A under current conditions in the Mortandad watershed.

The existing sources of surface contamination within Mortandad canyon are shown in Figure 4.3a2, which includes a map and a conceptual site exposure model. The map shows existing surface sources are primary outfalls associated with ongoing operations, although there are several legacy sources. There are also a number of nuclear facilities within this watershed. Also indicated are the monitoring stations that provide information that ensures control of exposures. The conceptual model highlights the pathway controls that apply to surface releases.

Figure 4.3a3 identifies the subsurface contaminant sources in the Mortandad watershed, which are primarily MDAs.

MDA C

The MDA C was established in May 1948 and used for the disposal of radioactive and hazardous waste through 1965. The depth to groundwater below MDA C is approximately 1175 ft (353 m). The site is enclosed by a fence and posted. The average depth of the MDA C disposal pits was 20 ft (6 m), and the average depth of shafts was about 16 ft (4.8 m). The pits were filled between 1948 and 1959, and the shafts were filled between 1958 and 1965. The pits are capped with vegetated crushed tuff and the caps are also sealed. Based on limited written records, the total radiological inventory estimates of MDA C are 196 Ci in pits and 49,483 Ci in shafts (Rogers 1977, 0216). This estimate includes 28 Ci of uranium (uranium-233, -234, -235, -236, and -238); 49,136 Ci of cesium-137; 31 Ci of strontium-90; 26 Ci of plutonium-239; 149 Ci of americium-241; 50 Ci of mixed fission products; and 200 Ci of mixed activation products. These estimates were sufficient for the purposes of calculating cumulative impacts from potential radiological releases from MDA C and MDA G in the composite analysis that supports the technical authorization basis for MDA G. MDA C is located upgradient of MDA G, and is higher in the Bandelier Tuff. By analogy to MDA G, MDA C is expected to isolate contamination well beyond 2035.

MDA J

MDA J was used to dispose of administratively controlled waste from 1961 through 1998. Historically, MDA J received waste that was potentially contaminated with trace quantities of non-reactive HE residues. Other wastes included asbestos and residual amounts of hazardous waste. Land farming also occurs at this site to bioremediate petroleum-contaminated soils from other LANL sites. MDA J was closed as a special waste landfill in 1999. It is controlled by LANL.

MDA L

The MDA L site was used for disposing of hazardous materials and liquid wastes and the storage of gas cylinders. Early operations between about 1959 and 1985 included disposing chemical wastes within unlined pits and shafts dug into the mesa. Since the implementation of RCRA in 1986, MDA L

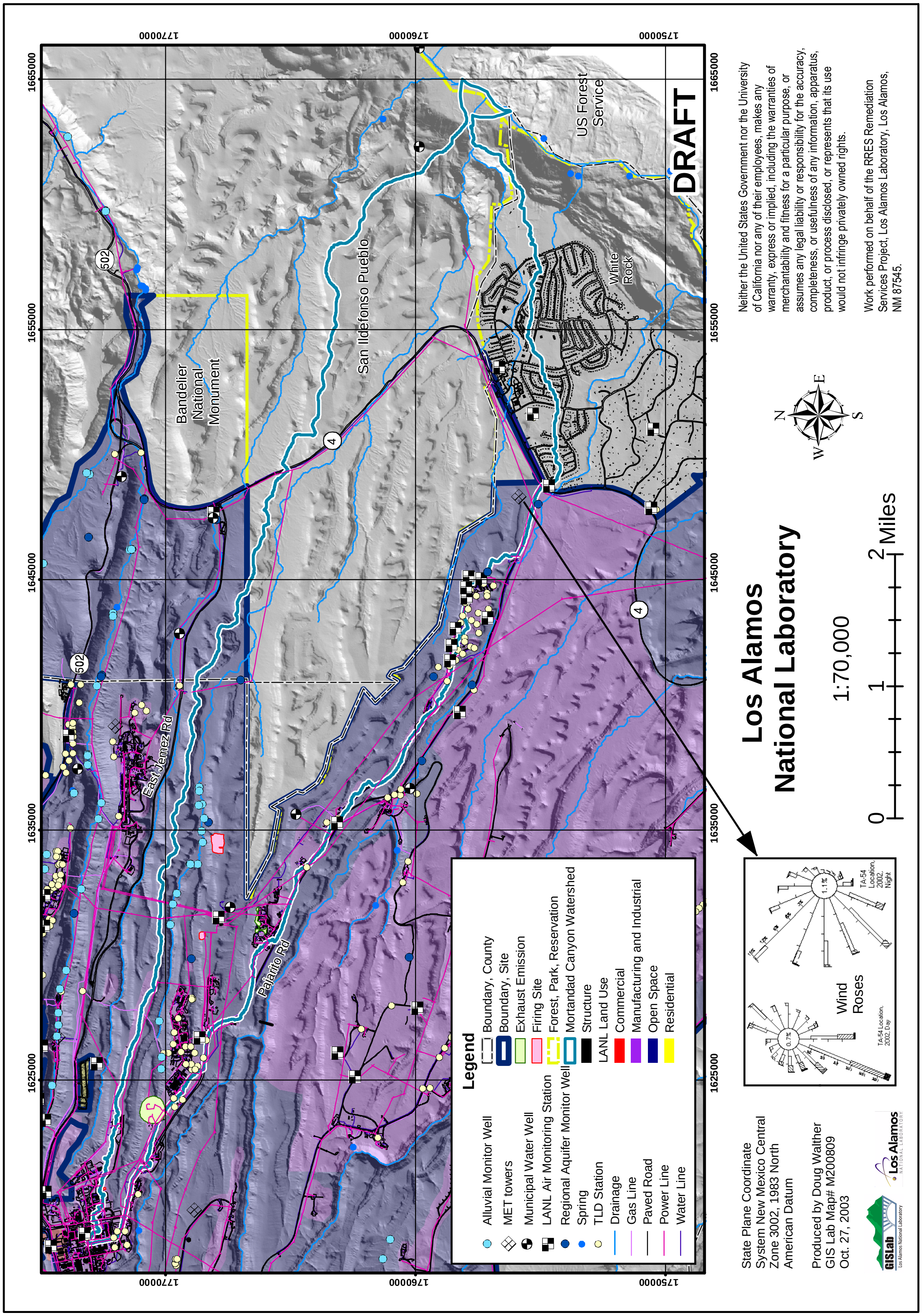


Figure 4.3a1. Hazard Area 3: Mortandad Canyon Watershed, Hazard Category A: airborne releases, Current state.

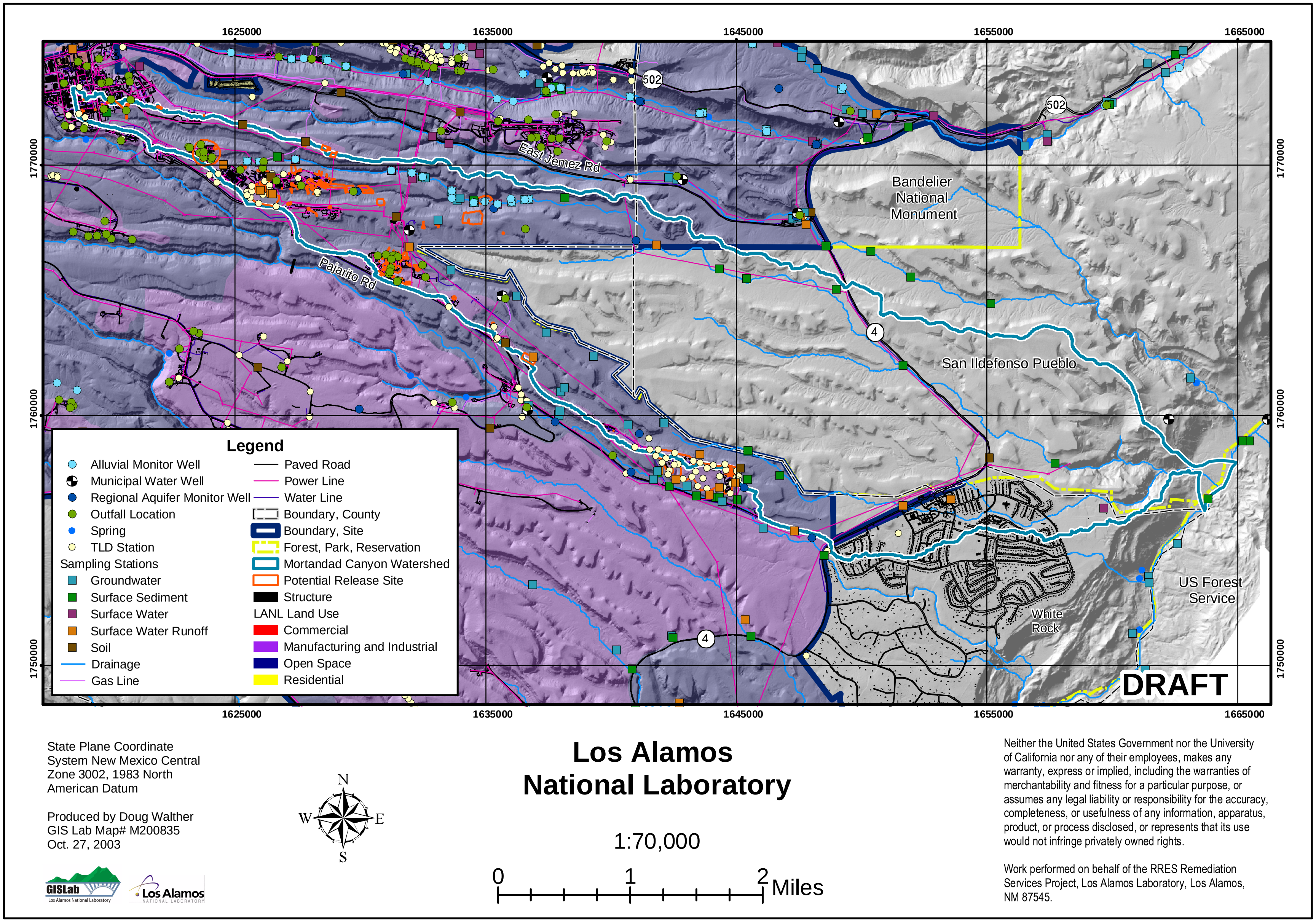


Figure 4.3a2. Hazard Area 3: Mortandad Canyon Watershed, Hazard Category B: surface releases, Current state.

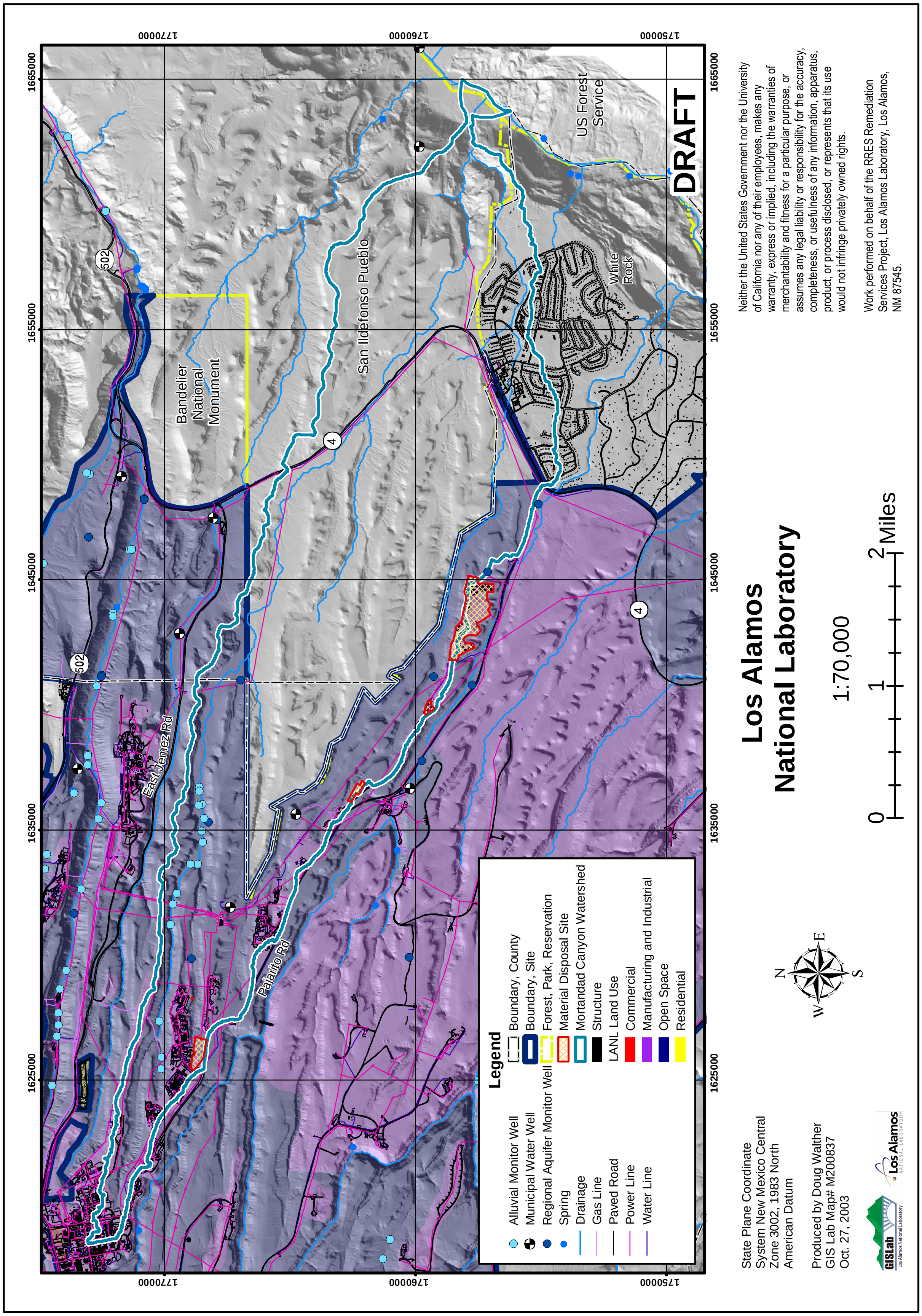


Figure 4.3a3. Hazard Area 3: Mortandad Canyon Watershed, Hazard Category C: subsurface releases, Current state.

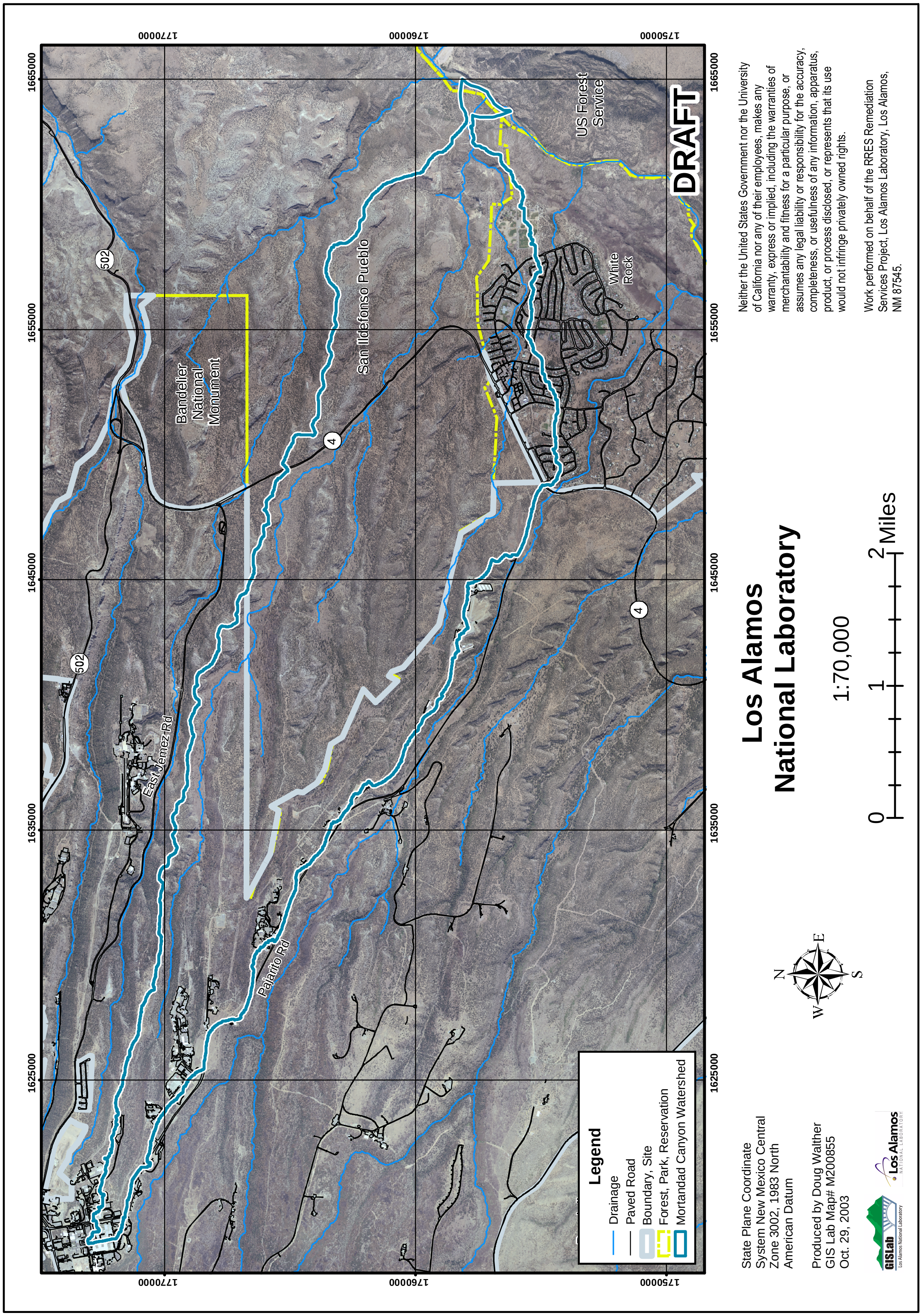


Figure 4.3a4. Hazard Area 3: Mortandad Canyon Watershed orthophoto map.

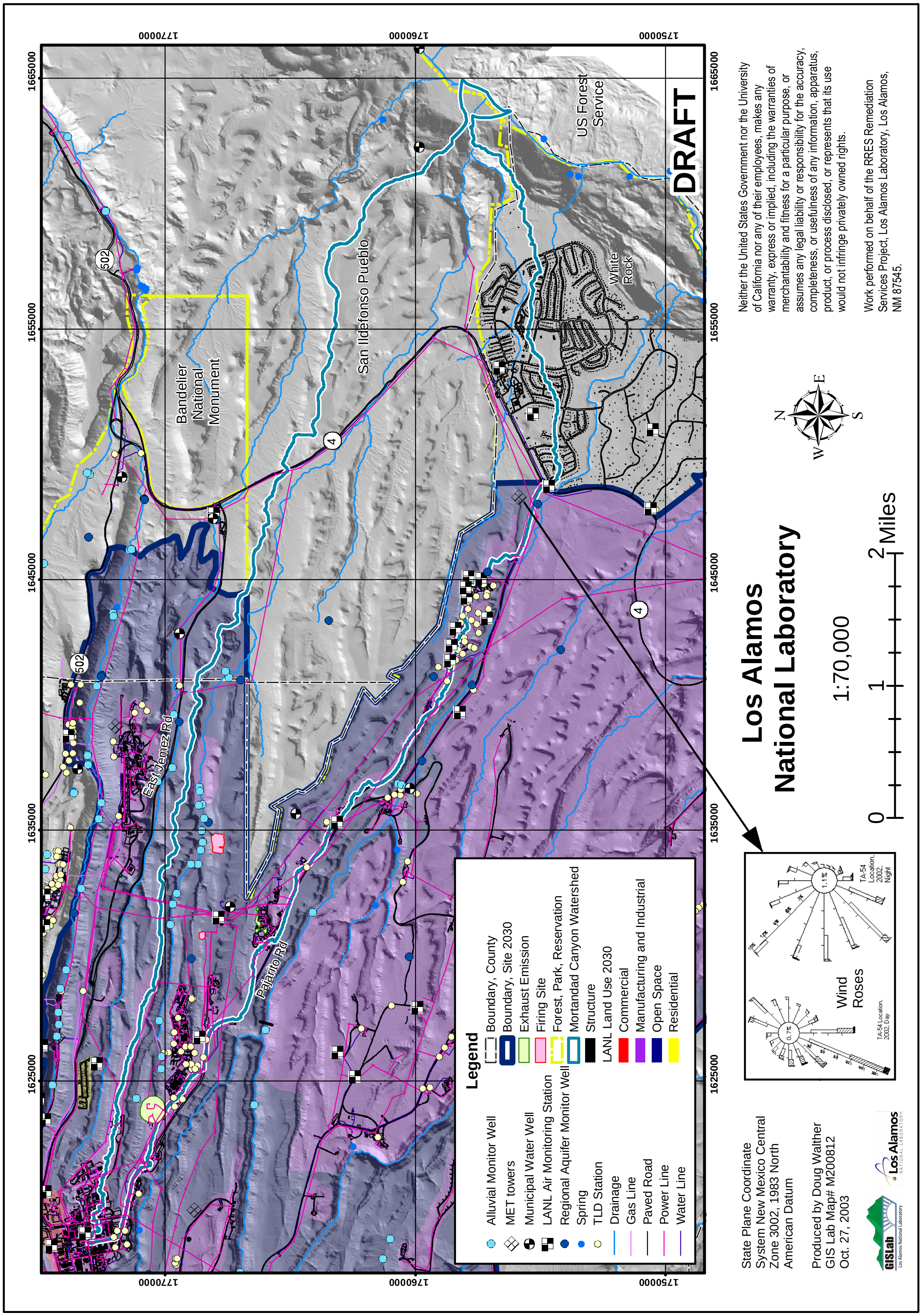


Figure 4.3b1. Hazard Area 3: Mortandad Canyon Watershed, Hazard Category A: airborne releases, End state.

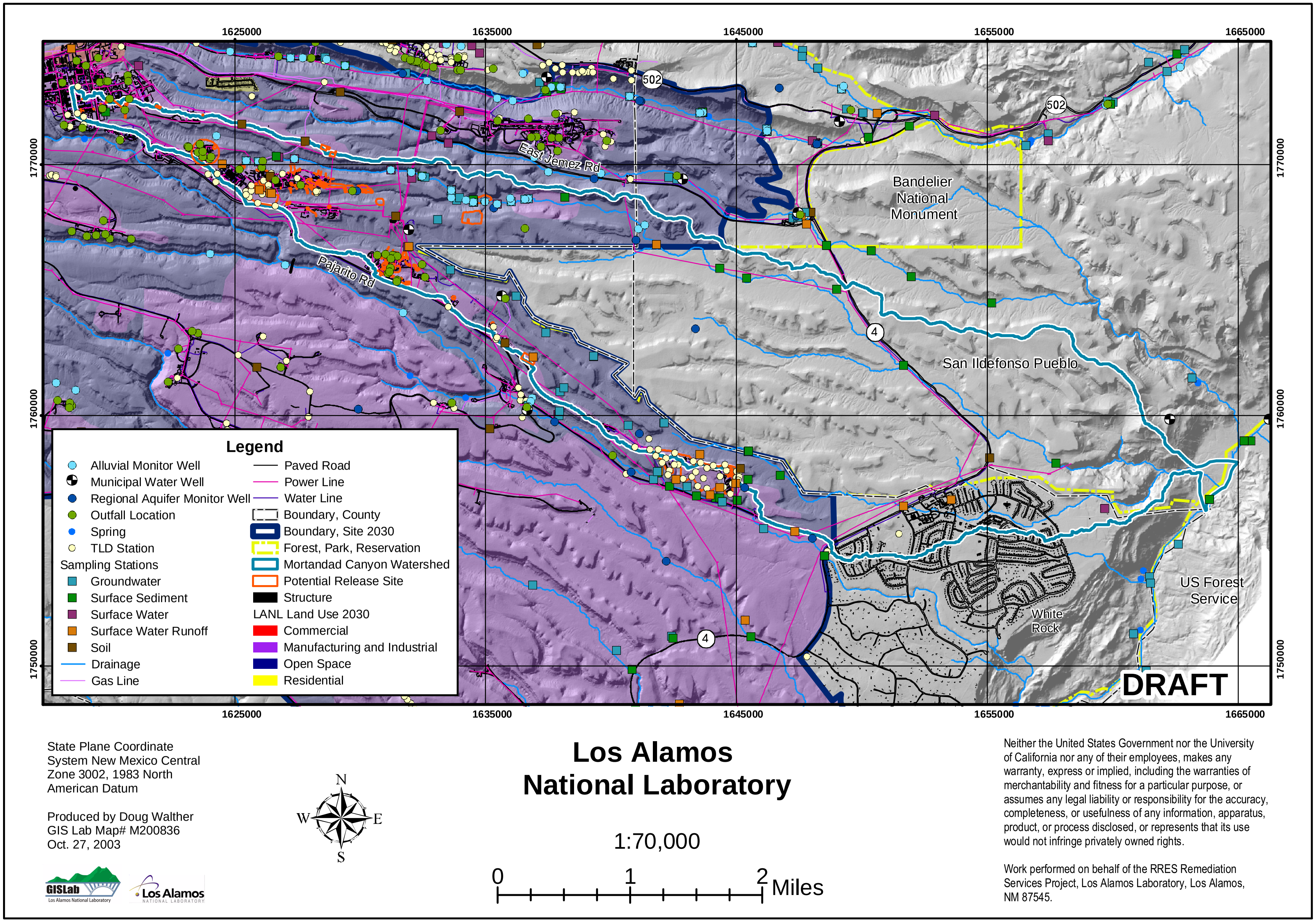


Figure 4.3b2. Hazard Area 3: Mortandad Canyon Watershed, Hazard Category B: surface releases, End state.

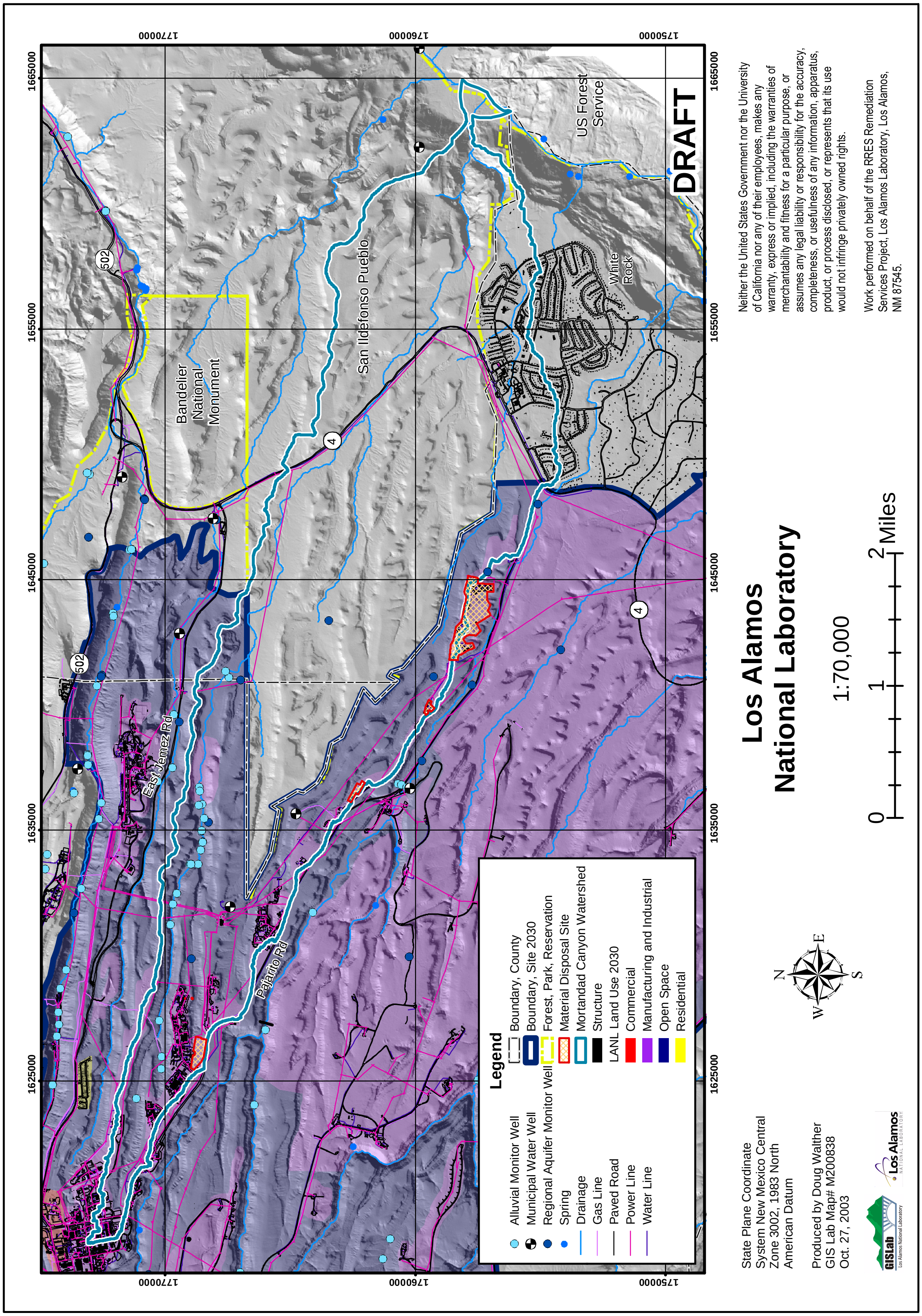


Figure 4.3b3. Hazard Area 3: Mortandad Canyon Watershed, Hazard Category C: subsurface releases, End state.

has been used in its present capacity for storage of RCRA waste, PCB waste, and some mixed waste (such as lead contaminated with radiation). In 1986, much of the previously used surface area was covered with asphalt to support surface structures. There is a well-characterized and analyzed vapor plume, containing primarily TCA and TCE. This plume is monitored to ensure worker safety, which provides a margin of safety for offsite exposures. In addition, three-dimensional simulation models have been developed to investigate the possible evolution of the plume under various scenarios, including the simultaneous rupture of multiple drums containing free product. The multiphase transport models demonstrate that the natural hydrological conditions and processes within the mesa can effectively attenuate both liquid and volatile chemicals such that concentrations in ambient air and groundwater will remain below regulatory standards and risk-based levels.

MDAs W and X

MDAs W and X contain waste from source preparation, radionuclide experimentation, and nuclear fission reactor development. MDA W is capped with concrete and sits on the southern edge of a mesa, with no potential for erosion of the cap. The depth to groundwater from the bottom of the carbon-steel-cased wells is around 1000 ft (300 m). MDA W was recommended for no further action after finding no evidence of a releases and robust engineering controls.

MDA X is the former site of the reactor from the Los Alamos Power Reactor Experiment No. 2 (LAPRE-II), which was buried in place after it was decommissioned in 1959. The depth to groundwater below the former location of MDA X is approximately 1160 ft (348 m). MDA X was remediated in 1991 as an interim action and recommended for no further action because all reactor-related equipment and contaminated soils were removed, and confirmatory sampling conducted on to ensure surface contamination was also removed.

The characteristics of the MDAs and the current state of monitoring and institutional controls that affect the exposures to hazards associated with MDAs in the Mortandad watershed are identified in the conceptual site exposure model attached to Figure 4.3a3.

4.3.2 Risk-Based End State

The risk-based end-state analogs of the current-state hazard-specific maps for the Mortandad watershed are shown in Figures 4.3b1, 4.3b2, and 4.3b3, for anticipated airborne, surface, and subsurface contaminant sources in 2035. Since surface contamination is the only significant hazard in this watershed, the end state reflects cleanup to industrial-use and/or recreational-use levels for lands that will be retained by LANL in 2035. The associated end-state conceptual site exposure model for Hazard Category B in Sandia watershed is attached to Figure 4.2b2. The natural processes that act to attenuate hazards associated with surface media discussed in Section 4.1.1 provide some control over both hazards and exposures, as indicated on the conceptual site exposure model.

4.4 Hazard Area 4 – Pajarito Watershed

The Pajarito watershed heads on the flanks of the Sierra de los Valles, on US Forest Service lands. It extends eastward for a length of approximately 15 mi across the south-central part of the Laboratory before entering Los Alamos County lands in White Rock. On this course it passes through numerous Laboratory technical areas. It covers a drainage area of approximately 8 mi^2.

On a regional scale, Pajarito Canyon is an interrupted stream attributable to several perennial springs in its upper reaches. These springs support flow in a perennial reach of the canyon, followed by an intermittent reach to within about 0.5 mi west of the Laboratory boundary. At about 1.0 mi east of the western Laboratory boundary, Homestead Spring supports another perennial reach for at least several hundred yards, followed by an intermittent and/or ephemeral reach that may extend down to near its confluence with Threemile Canyon.

East of this confluence, Pajarito Canyon is ephemeral across Laboratory land and Los Alamos County land through White Rock, down to a point about 0.4 mi upstream from its confluence with the Rio Grande. There a large perennial spring fed by the main aquifer, commonly called Pajarito Spring, supports perennial flow for the remainder of the distance to the Rio Grande.

In most years, snowmelt flows in the watershed for periods ranging from a few days to a few weeks. Snowmelt occasionally extends downstream as far as the confluence with the Rio Grande.

The primary LANL use of lands within the Pajarito watershed has been as the location of the Los Alamos Critical Experiments Facility and surface and subsurface MDAs, as a buffer zone for mesa-top firing site activities, and to a lesser degree for liquid waste disposal. These operations have been conducted in and have possibly discharged to Pajarito watershed and its tributaries since 1943. These early discharges were associated with outfalls, surface runoff, and dispersion from firing sites located. Additional discharges began with the continued expansion of LANL operations to new sites in the 1950s through the 1970s.

The Pajarito watershed encompasses land managed by LANL, land owned by the US Forest Service, Los Alamos County land, and privately owned land. Currently, hiking trails provide recreational access to the portion of the canyon within the LANL boundary and on Los Alamos County land. Local residents use a portion of the canyon east of the Laboratory boundary including White Rock Canyon for activities such as hiking, jogging, and rock climbing.

A significant portion of the residential community of White Rock is located within the Pajarito Canyon drainage downgradient of the LANL boundary. Residents have unrestricted access to the main drainage channel.

4.4.1 Current State

The current hazards, hazard control, and exposure controls currently present in the Pajarito watershed are shown in map-format and conceptual site exposure model format in Figure 4.4a1. The current airborne hazards include exhaust from facilities and open-air explosives detonations.

Figure 4.4a2 identifies the locations and associations of current surface releases in the Pajarito watershed, again in map and conceptual site model format. There are a number of liquid discharges from operating facilities, as well as potential release sites, including surface contamination collocated with MDA F subsurface hazards. The institutional exposure controls include monitoring of surface media, and access limitations. These controls, combined with natural attenuation by surface water and sediment transport discussed in Section 4.1.1 act to reduce the risks associated with exposures to surface contamination under current conditions.

Figure 4.4a3 identifies the locations of subsurface sources within the Pajarito watershed. It identifies three MDAs. The associated conceptual site exposure model identifies the institutional and natural controls that mitigate the potential for risk-significant exposures to these subsurface hazards. The characteristics of the MDAs contribute to an element of exposure control.

MDA F

MDA F consists of two fenced areas used in 1945 for surface detonation (“flashing”) of defective explosive lenses manufactured for use in the Fat Man implosion weapon. Some of these lenses contained Baratol, which contains barium and trinitrotoluene (TNT). In 1946, a pit was excavated to dispose of large classified objects that could not be easily cut. The objects were buried to protect their classification. In 1947, another pit was excavated to dispose other classified material. Two large disturbed areas, which may be these two pits, are visible on 1954 aerial photographs. From 1949 through 1951, work orders were written for three smaller pits to be used for occasional disposal. The locations and contents of these pits are unknown. From 1950 to 1952, three shafts were drilled to dispose spark gaps containing small amounts of cesium-137. The fenced have been continually monitored for radioactivity since 1981 as part of LANL’s environmental surveillance program. No readings above background have been observed. The depth to groundwater below MDA F is approximately 1275 ft (383 m).

MDA G

MDA G is a 100-acre (40-ha) site that has served as the Laboratory’s principal radioactive solid waste storage and disposal site since the Laboratory’s routine operations began there in 1959. The approximate average depth to groundwater is 1000 ft. MDA G will continue operating in its current capacity for the foreseeable future. Disposal units (pits and shafts) containing waste disposed before

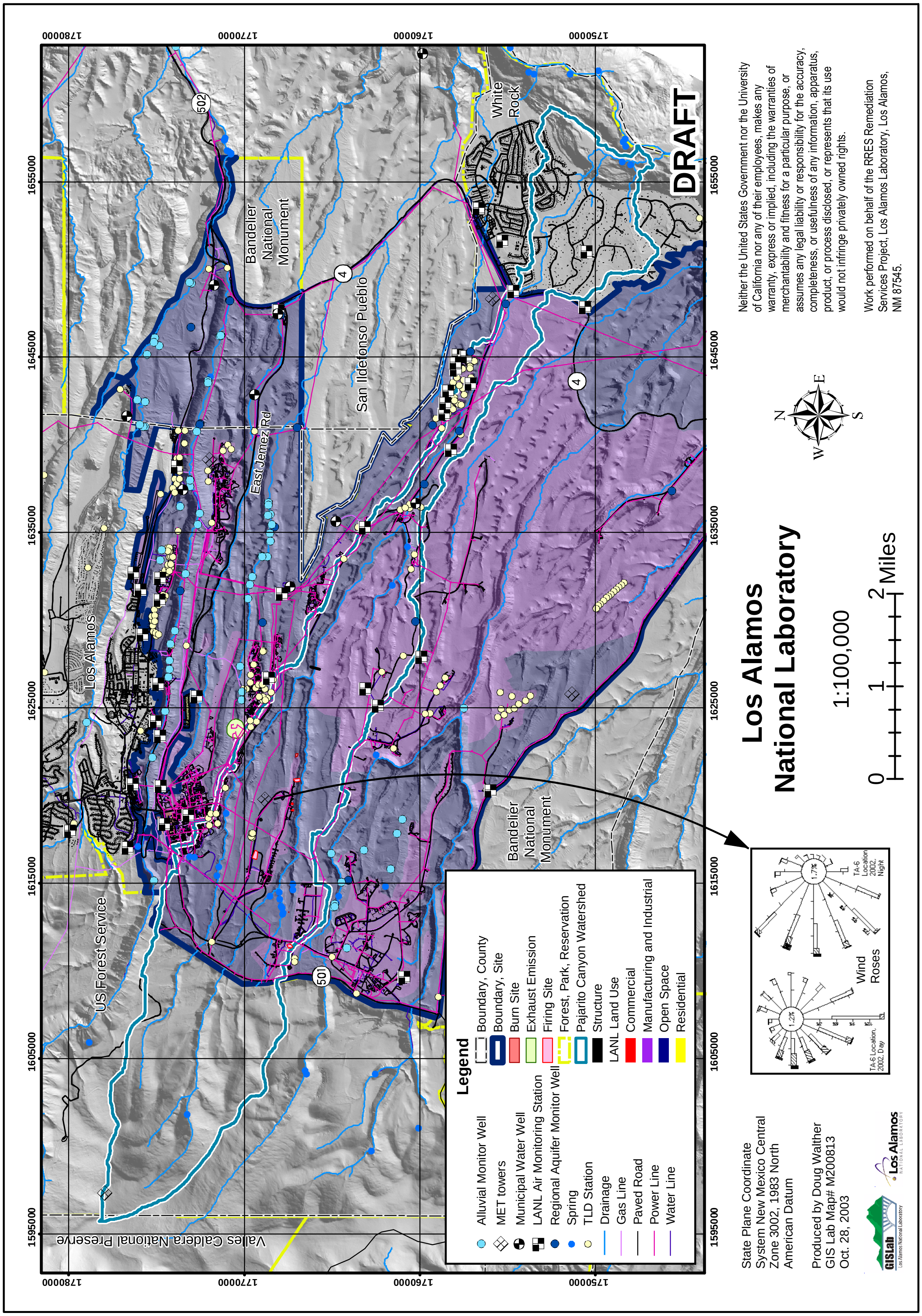


Figure 4.4a1. Hazard Area 4: Pajarito Canyon Watershed, Hazard Category A: airborne releases, Current state.

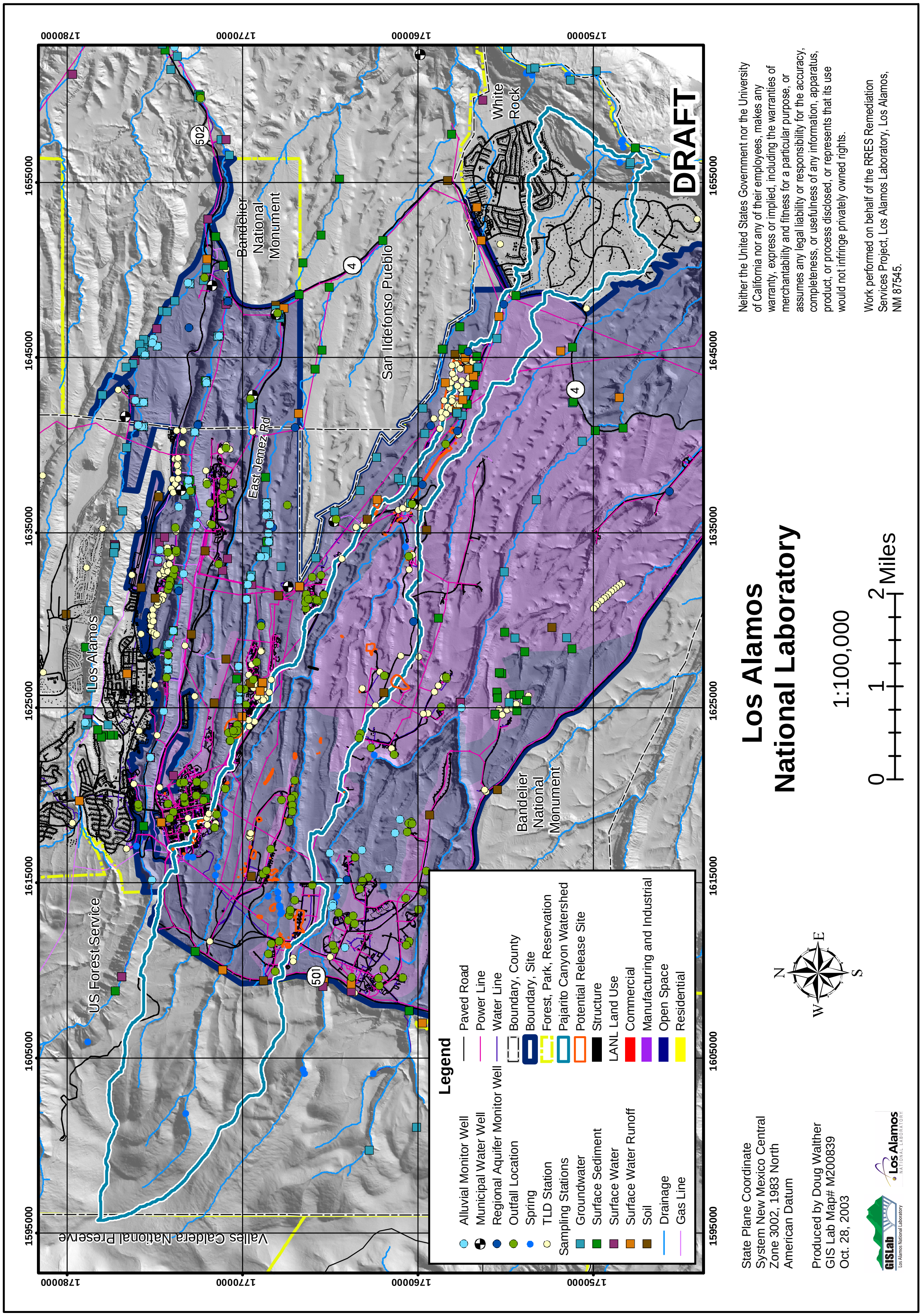


Figure 4.4a2. Hazard Area 4: Pajarito Canyon Watershed, Hazard Category B: surface releases, Current state.

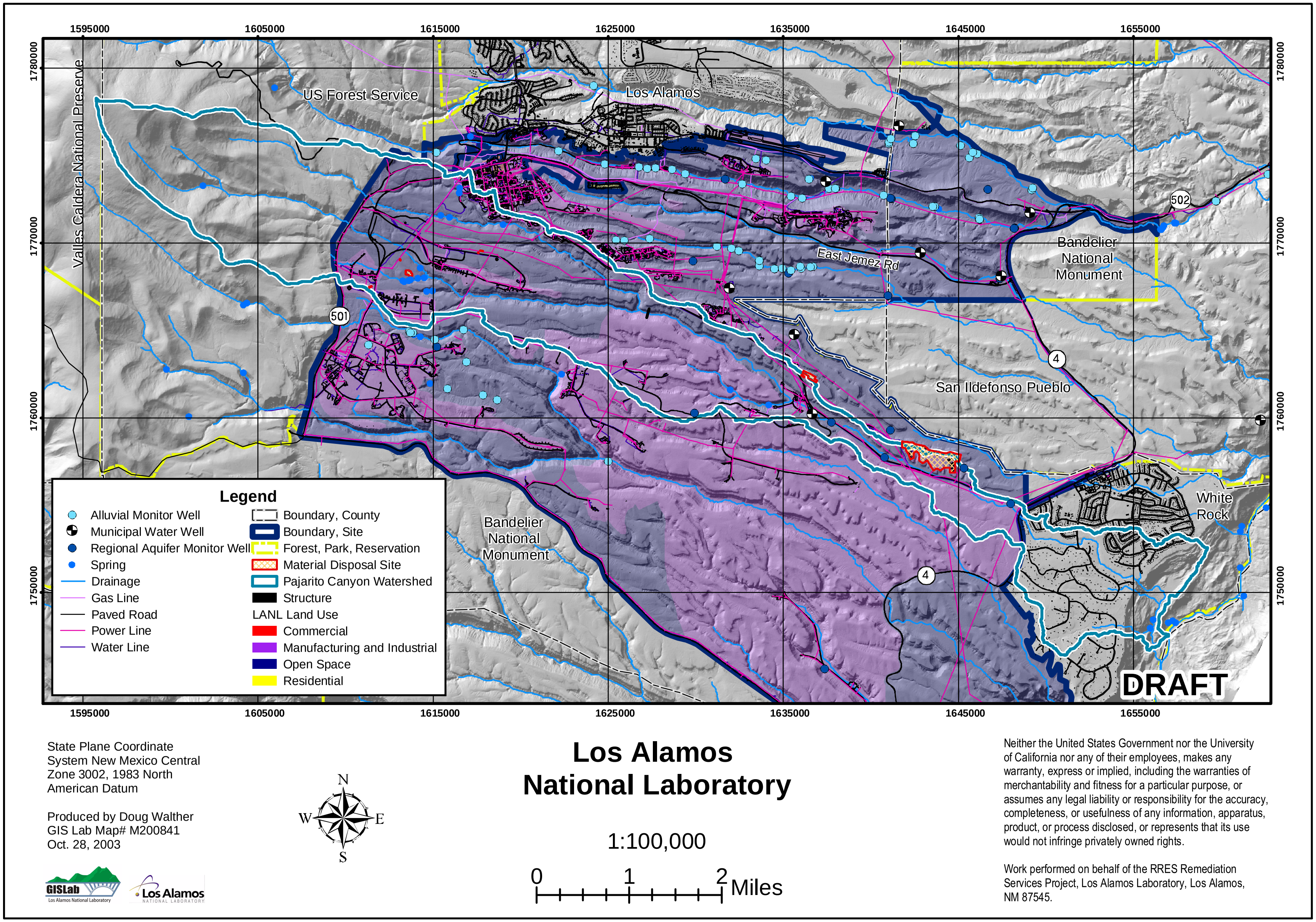


Figure 4.4a3. Hazard Area 4: Pajarito Canyon Watershed, Hazard Category C: subsurface releases, Current state.

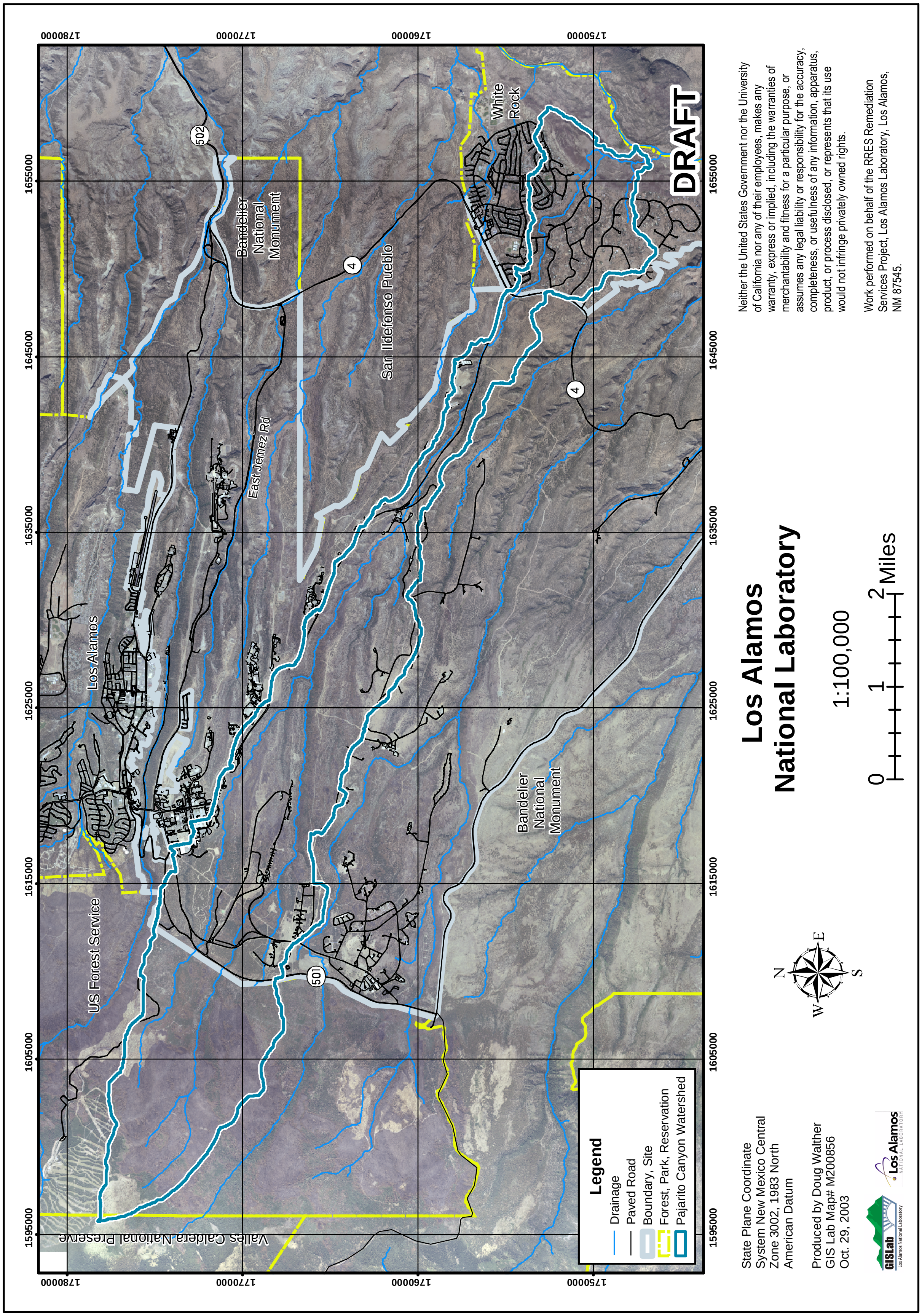


Figure 4.4a4. Hazard Area 4: Pajarito Canyon Watershed orthophoto map.

1988 are subject to cleanup. From 1959 to 1970 nearly all of the Laboratory's solid radioactive waste was disposed at MDA G. It was interred into pits and into lined and unlined shafts dug into the mesa. The depth of these pits and shafts is approximately 60 ft (18 m). Layers of waste in pits have been backfilled with clean excavated materials (crushed tuff), and filled pits have been covered with at least 1 m (3 ft) of crushed tuff and about 5 in. (12 cm) of topsoil, which has been re-vegetated with native grasses. Filled shafts have been capped with crushed tuff, concrete, or both.

In 1971, the Laboratory began segregating radioactive waste into two categories differentiated by the concentration of transuranic radioisotopes present in the waste. Since that time, transuranic waste has been retrievably stored at MDA G, and only low-level radioactive waste has been permanently disposed. Since the implementation of RCRA in 1986, low-level radioactive waste that also meets the definition of a RCRA listed or characteristic hazardous waste has been segregated and stored above ground at MDA G.

MDA G has undergone intensive scrutiny and as both a permitted RCRA storage facility, and an authorized DOE LLW disposal facility, and intensive investigation as a cleanup site. There are known to be subsurface vapor-phase plumes of volatile organic compounds (VOCs) and tritium, but no other releases have been found in the subsurface.

In 1997, the performance assessment and composite analysis of MDA G (Hollis et al. 1997, 63131) was published and approved to authorize continued disposals pursuant to DOE requirements. In addition, an RFI report for MDA G was submitted to NMED in 1999. The risk assessment performed for the MDA G RFI builds on the performance assessment and composite analysis, and it confirms the conclusions of the performance assessment, demonstrating that the administrative and natural controls currently in place are effective at containing contamination and attenuating potential releases such that no exceedance of regulatory or risk-based standards is anticipated.

MDA H

MDA H is a fenced 0.3-acre (0.12-ha) rectangular area measuring 200 ft by 70 ft (60 m by 21 m) on the same mesa as MDA G. The depth to groundwater from the surface at MDA H is approximately 1000 ft. Nine shafts were used for the disposal of classified wastes from 1960 to 1986. Records indicate that one shaft may contain a volume of 990 ft^3 (30 m^3) of hazardous waste. The shafts are 6 ft (1.8 m) in diameter and approximately 60 ft (18 m) in depth for a total disposal capacity of approximately 14,000 ft^3 (410 m^3). Waste disposal logs show that nearly every shaft received the following materials: weapons components, classified documents and paper, aluminum, plastic, stainless steel, rubber, graphite shapes, weapon mockups, depleted uranium scraps and classified shapes, film, prints and slides, classified shapes contaminated with high explosives (HE), and graphite reactor fuel rods. In addition, RCRA hazardous metals were disposed in many of the shafts. Eight of the nine shafts are capped by a 3-ft (1-m) layer of concrete and a 3-ft (1-m) layer of soil. One has a locked steel plate as a cover. A risk assessment confirms the long-term stability and performance of the site in its current state.

MDA Q

MDA Q is a 0.2-acre (0.01-ha) site where naval guns used during the development of Little Boy were buried in 1946. MDA Q occupies an irregularly shaped rectangular area with dimensions of approximately 270 ft by 260 ft (81 m by 78 m). The depth to groundwater below MDA Q is approximately 1200 ft (360 m).

4.4.2 Risk-Based End State

Attributes of the risk-based end state planned for the Pajarito watershed are shown in Figure 4.4b1, 4.4b2, and 4.4b3, for airborne, surface, and subsurface hazards, respectively. Each hazard category has an associated conceptual site exposure model. The conceptual site exposure model identifies the controls that are expected to be achieved consistent with the risk-based end state through 2035. It is anticipated that many of LANL's core-mission operations will continue to be conducted within the Pajarito watershed.

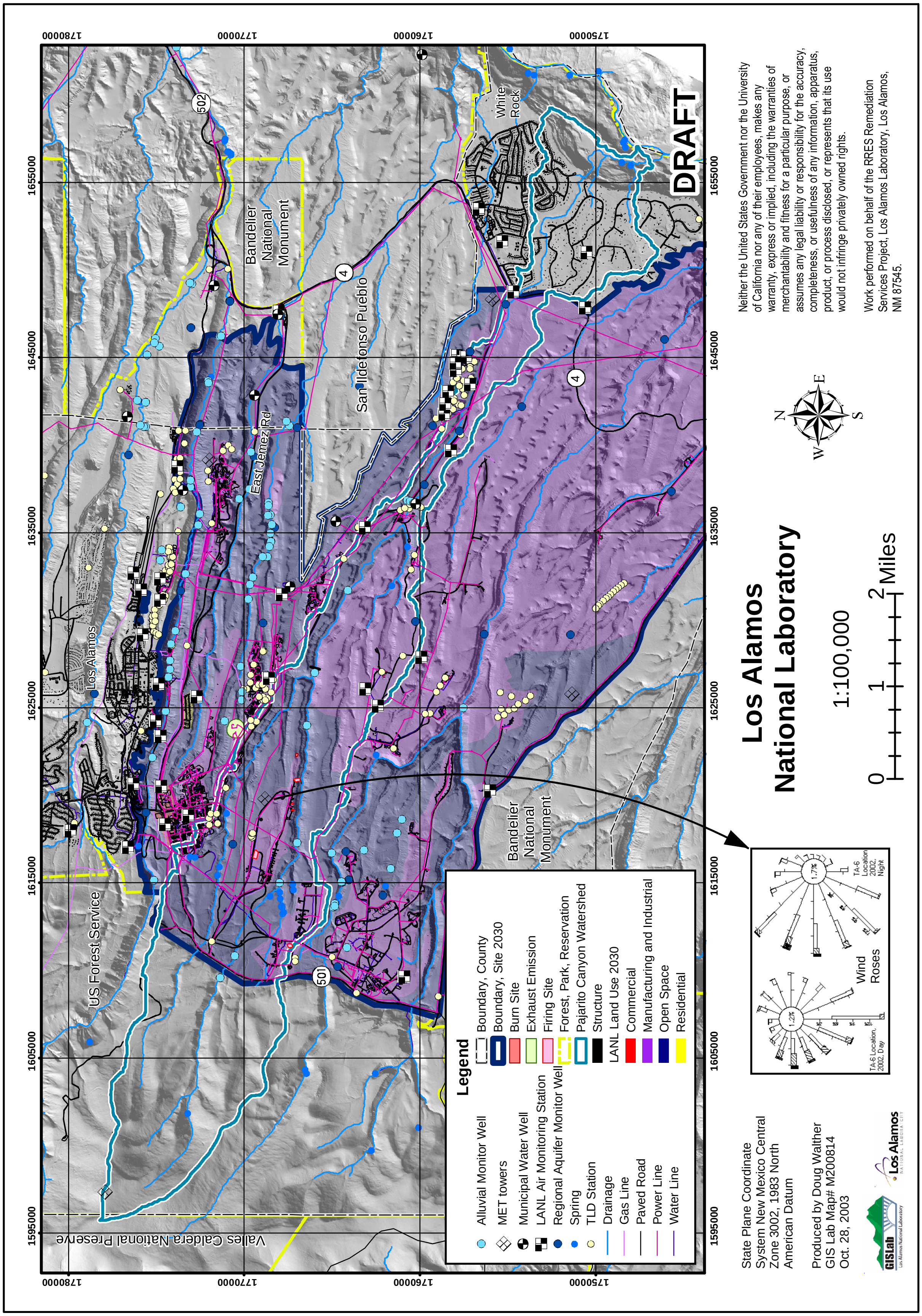


Figure 4.4b1. Hazard Area 4: Pajarito Canyon Watershed, Hazard Category A: airborne releases, End state.

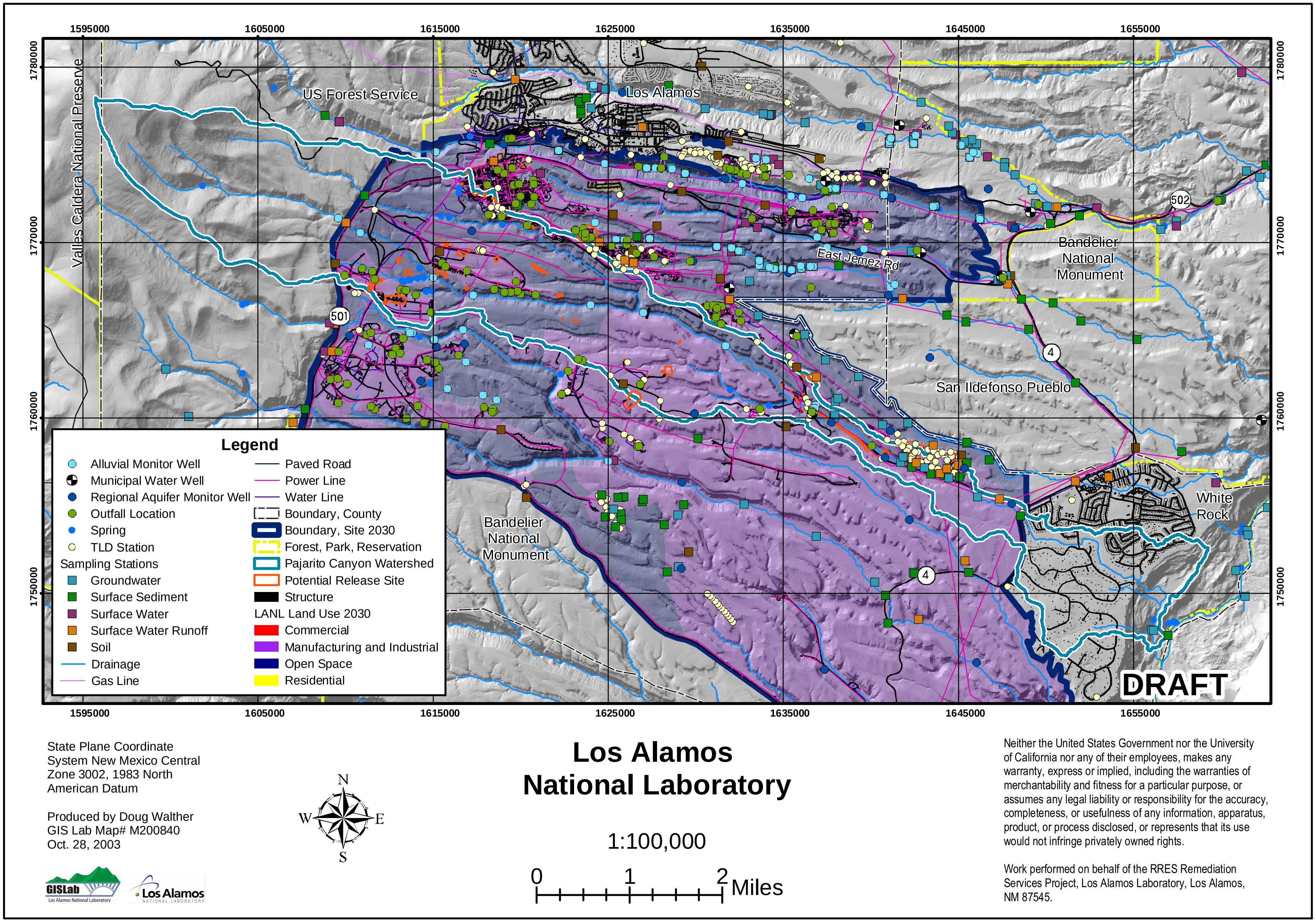


Figure 4.4b2. Hazard Area 4: Pajarito Canyon Watershed, Hazard Category B: surface releases, End state.

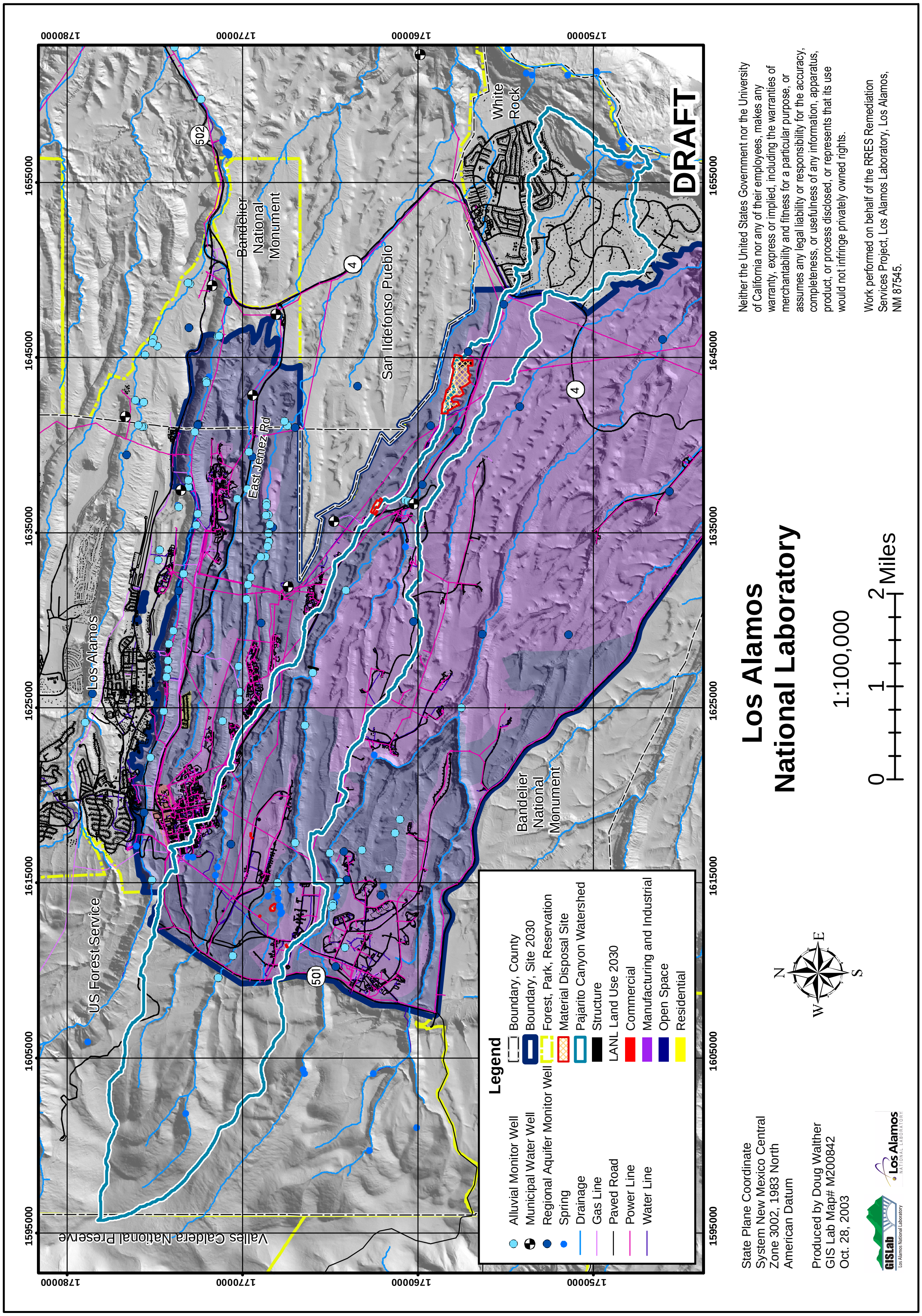


Figure 4.4b3. Hazard Area 4: Pajarito Canyon Watershed, Hazard Category C: subsurface releases, End state.

4.5 Hazard Area 5 – Water Canon de Valle Watershed

The Water/Canon de Valle watershed heads on the flanks of the Sierra de Los Valles and drains a total area of about 10 mi^2. It originates on US Forest Service lands and extends across the southern portion of the LANL all the way to its confluence with the Rio Grande in White Rock Canyon.

On a regional scale, the Water/Canon de Valle watershed is an interrupted stream attributable to several perennial springs in the upper and middle reaches. These springs support perennial reaches followed by intermittent reaches limited to the area west of the LANL boundary and state road NM 501.

This drainage passes near numerous sites that have been used for testing and development of weapons components. While several of these sites have been inactive since the early 1950s, others have remained in use to the present. Potential contaminant releases into the drainage as a result of these operations include HE, radionuclides, and metals.

Currently, hiking trails provide recreational access to the portion of the drainage west of the LANL boundary on Forest Service land. Local residents and LANL employees use this area for activities such as hiking, biking, jogging, and camping.

Frequently, anthropogenic flow occurs in a canyon reach that extends from near the southwest corner of the LANL boundary to a point slightly downstream of the confluence with its tributary, Cañon de Valle. This water is spring water that is piped to LANL facilities where it was once used for industrial supply. When released this water flows through stormwater drainages back into the watershed drainage.

4.5.1 Current State

Figure 4.5a1 shows the sources of airborne contamination in the Water/Canon de Valle watershed under current conditions, and the associated conceptual site exposure model. Existing operational sources of airborne contamination include open-air firing sites, open-air burn sites, and exhaust emissions. All are permitted and monitored to ensure compliance with applicable worker safety and environmental regulations, which account for the pathway controls in the conceptual site exposure model.

Figure 4.5a2 shows the current sources of surface contamination in the Water/Canon de Valle watershed, including many liquid outfalls associated with ongoing operations, and many potential release sites. One potential surface release site is MDA S, which in this way is unlike most other MDAs. MDA S is a fenced, active experimental plot measuring approximately 10 ft by 10 ft (3 m by 3 m). The depth to groundwater below MDA S is approximately 1160 ft (348 m). The area is used to study the effect of soil and weather on the decomposition of explosives. The area, which slopes to the southwest, is well vegetated with grasses and weeds, locust shrubs, and two small ponderosa pines. Experiments to determine the persistence of explosives in soil were initiated in March 1965. Some experiments are still active, having less than 80 g (0.18 lb.) of HE in their inventory.

Operations contributing to the surface contamination in the Water/Canyon de Valle watershed are related to the production of HE and include casting, pressing, and machining of HE; assembly of explosive test devices; fabrication of plastic components; development of new materials; and nondestructive examination. These operations have been conducted since the early 1940s and has recently had a high-pressure tritium facility installed. As indicated in the conceptual site exposure model accompanying the map of surface releases, both institutional and natural controls reduce the potential for harmful exposures to surface contamination.

The existing subsurface sources of contamination in the Water/Canon de Valle watershed shown in Figure 4.5a3 include several relatively small MDAs, just visible in the prescribed mapping format.

MDA N

MDA N is a pit containing the remnants of several structures and rubble from a firing site that had been exposed to either explosives or chemical contamination including mercury, thorium, and photographic solutions. The depth to groundwater beneath MDA N is approximately 1170 ft (351 m). MDA N was opened in 1962 and closed before 1965. The pit is covered with native backfill and vegetated.

MDA R

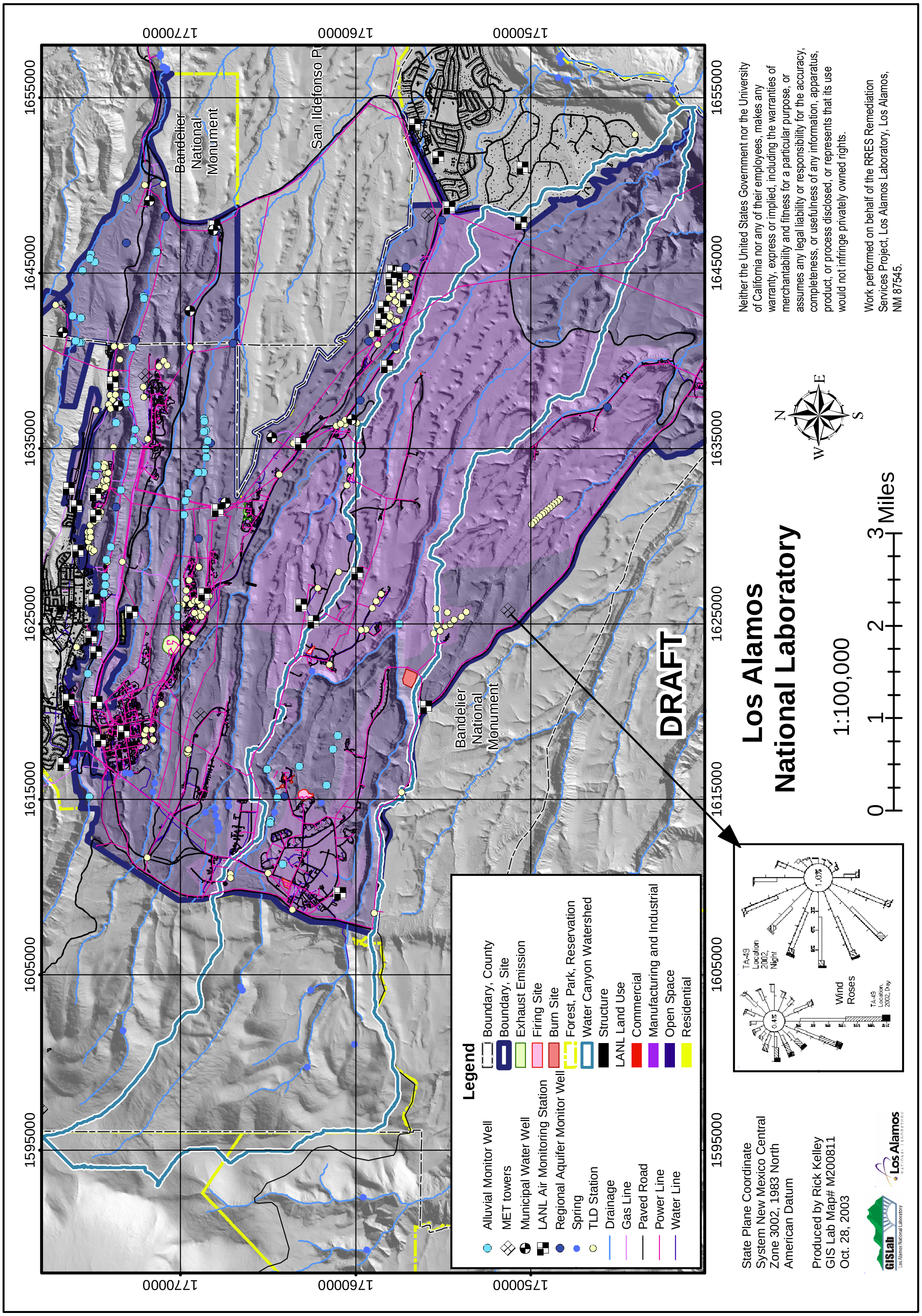


Figure 4.5a1. Hazard Area 5: Water Canyon Watershed, Hazard Category A: airborne releases, Current state.

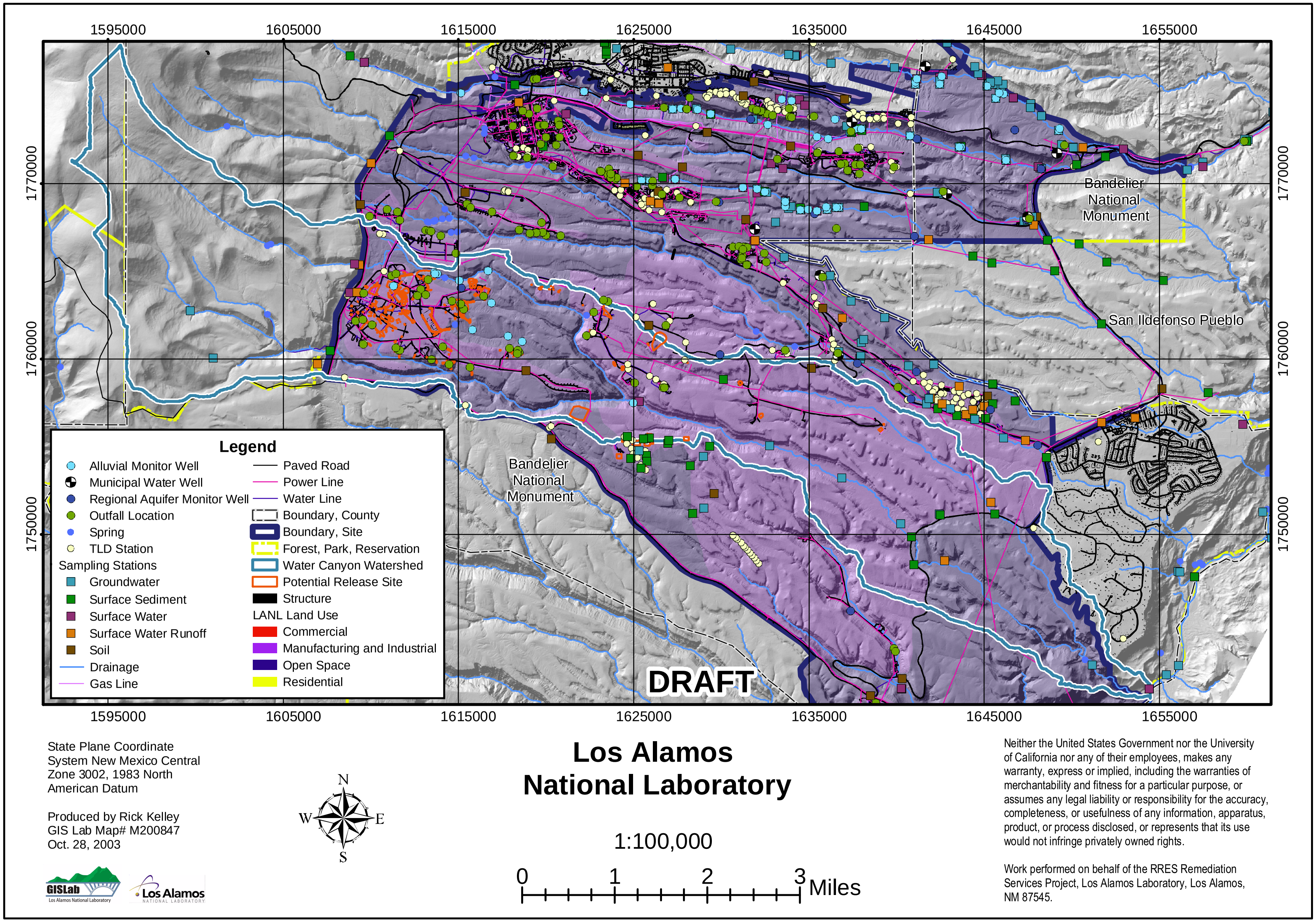


Figure 4.5a2. Hazard Area 5: Water Canyon Watershed, Hazard Category B: surface releases, Current state.

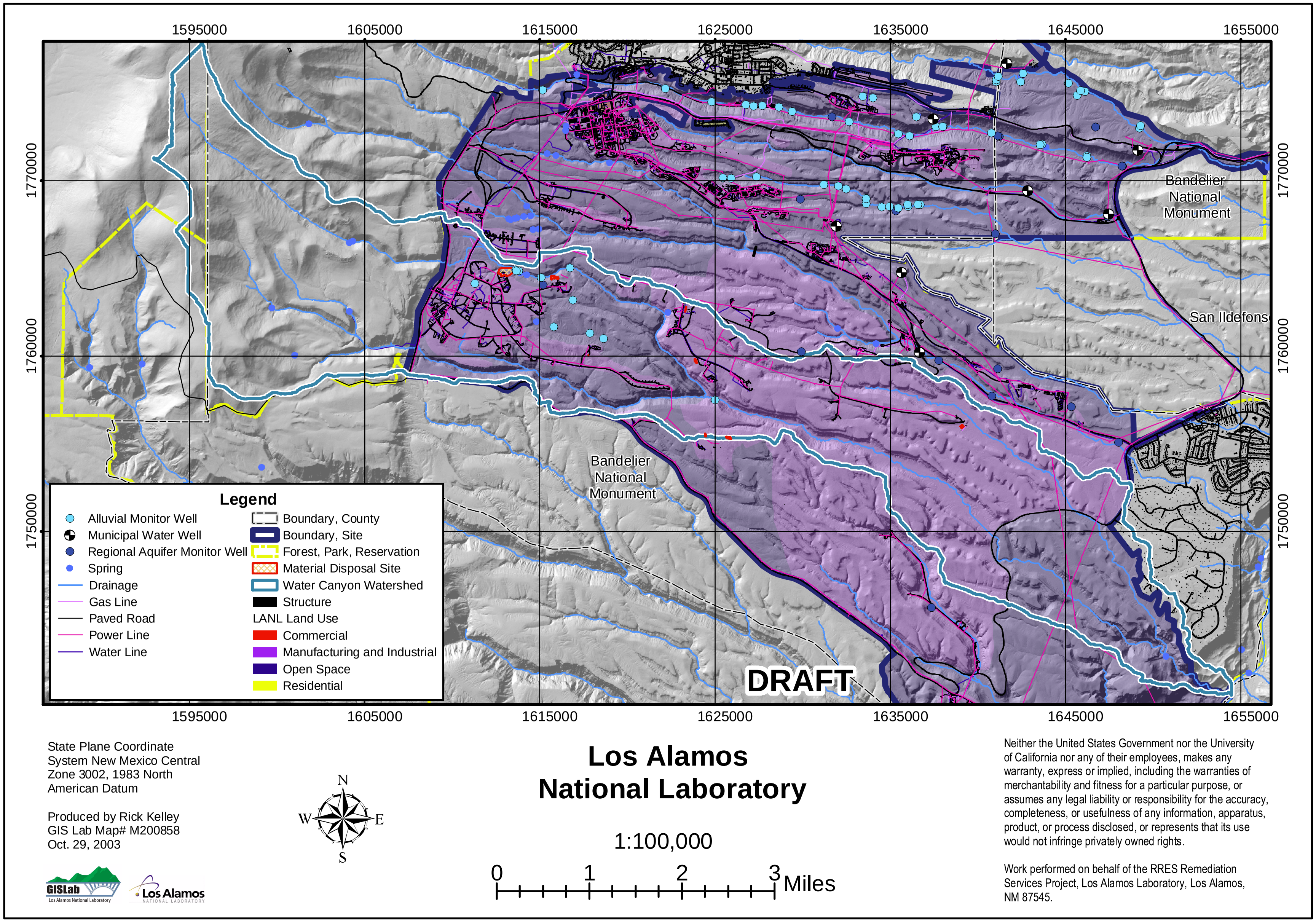


Figure 4.5a3. Hazard Area 5: Water Canyon Watershed, Hazard Category C: subsurface releases, Current state.

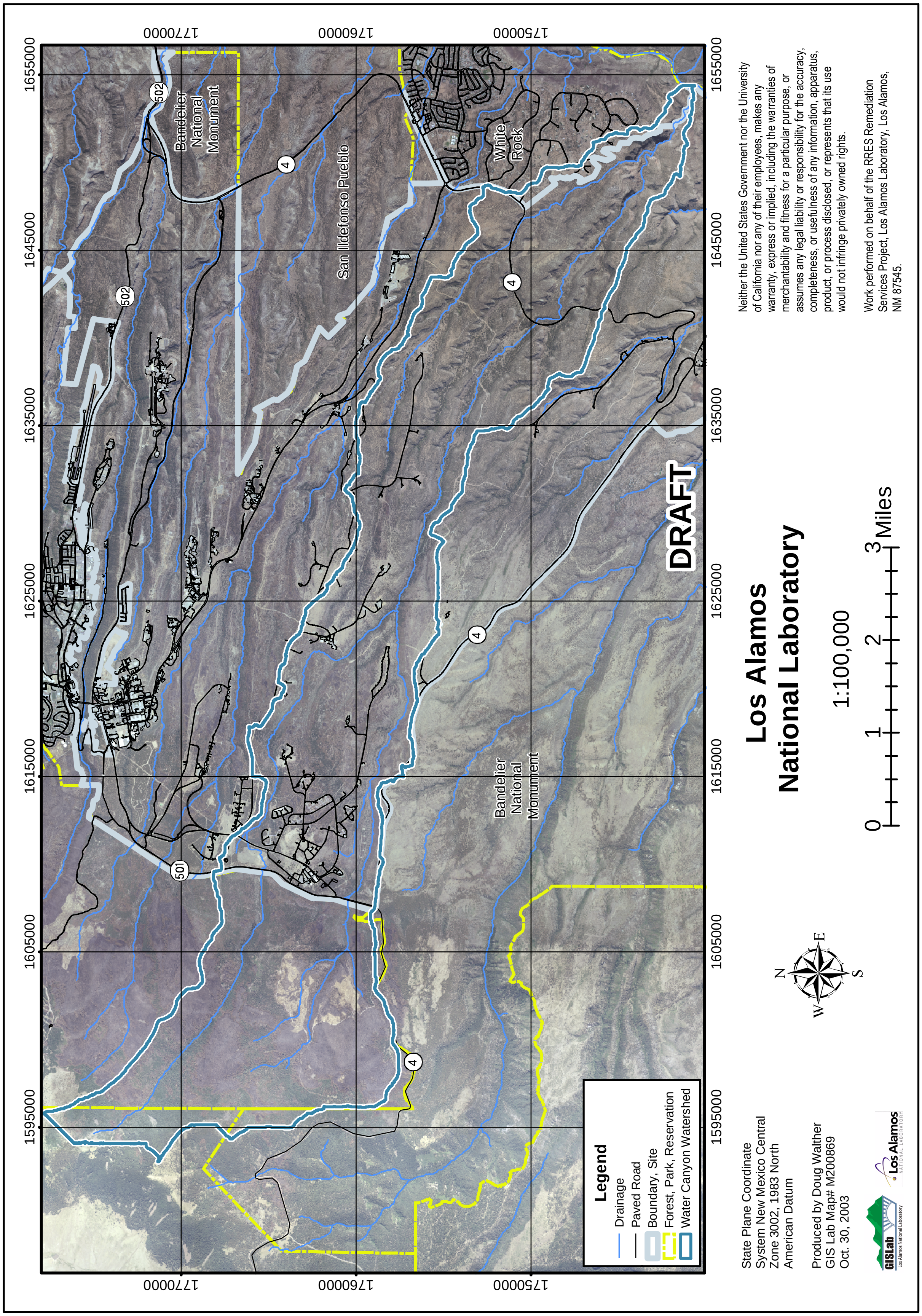


Figure 4.5a4. Hazard Area 5: Water Canyon Watershed orthophoto map.

MDA R is a historic HE burning ground and associated canyon side disposal area covering 11.5-acre (4.6-ha). The depth to groundwater beneath MDA R is approximately 1240 ft (372 m). MDA R was an active disposal unit from 1945 until 1951.Likely constituents at MDA R (based on analogy with the modern burning ground and MDA P) are HE, including chunk HE and barium. There are significant amounts of debris along the north side of MDA R. A geophysical survey at MDA R suggests that the depth of waste at MDA R is shallow.

MDA Z

MDA Z was used between 1965 and 1981 for the disposal of construction debris, including pieces of cement and rebar of various sizes, used concrete bags, steel blast mats from tests at PHERMEX, and other debris. Pieces of partially burned wood are visible. The landfill is roughly rectangular and measures approximately 200 ft by 50 ft (60 m by 15 m). Waste appears to have been placed in a naturally occurring depression; concrete filled sandbags are visible, which were probably piled as a retaining wall, and other debris was probably filled in behind it. One face grades to native soil, while the other is exposed and stands approximately 15 ft (4.5 m) high. Most of the debris on the exposed face is not covered with soil and is exposed to wind, rain, and snowmelt. Contaminants at the site include metals from wire, blast mats, VOCs and/or semivolatile organic compounds from charred wood, road and construction debris, and radioactive substances (e.g. from the blast mats). Chunks of uranium are visible at this site. The depth to groundwater below MDA Z is approximately 1200 ft (360 m).

MDA AA

MDA AA is a site containing up to four trenches dug in mid-1960s to burn and dispose debris and sand from the firing sites. The depth to groundwater below MDA AA is approximately 770 ft (231 m). The trenches provided safety and administrative controls for explosives and for materials possibly contaminated with explosives; they also reduced the volume of firing site debris. The last active trench on the south side of MDA AA was closed May 12, 1989 in accordance with New Mexico solid waste regulations. After the last trench was filled with burned debris and covered with clean soil, the entire MDA AA trench area was graded to lessen the potential of stormwater run-on and run-off that would erode the site and impact the Water Canyon watershed. Combustible firing site debris, such as wood, is still burned on the surface of a permitted burn area 100–300 ft (30–90 m) west of MDA. AA.

4.5.2 Risk-Based End State

Figures 4.5b1, 4.5b2, and 4.5b3 present maps for airborne, surface, and subsurface contamination in the Water/Canon de Valle watershed, consistent with the risk-based end state vision in 2035. Continued use of this watershed for NNSA mission-critical experimental operations is expected through 2035, as suggested by the similarity in the current- and risk-based end-state maps.

4.6 Hazard Area 6: Ancho Watershed

The Ancho watershed heads on the plateau within the Laboratory near the middle of the southern Laboratory boundary has a total drainage area of about 4.6 mi^2. It extends for about 7.3 mi across Laboratory land all the way to its confluence with the Rio Grande.

Ancho Canyon is ephemeral within the LANL boundary and on to the east past state road NM 4, to a point about 0.8 mi upstream from its confluence with the Rio Grande. At that point, a perennial spring, fed by the main aquifer supports a perennial flow all the way to the confluence with the Rio Grande. No significant snowmelt occurs in this drainage.

A portion of this watershed east of state road NM 4 is used considerably for hiking access to the Rio Grande.

4.6.1 Current State

Figures 4.6a1, 4.6a2, and 4.6a3 present maps and associated conceptual site exposure models for airborne, surface, and subsurface contamination (respectively) in the Ancho watershed under current conditions. The sources of airborne and surface contamination are similar to those in the Water/Canon

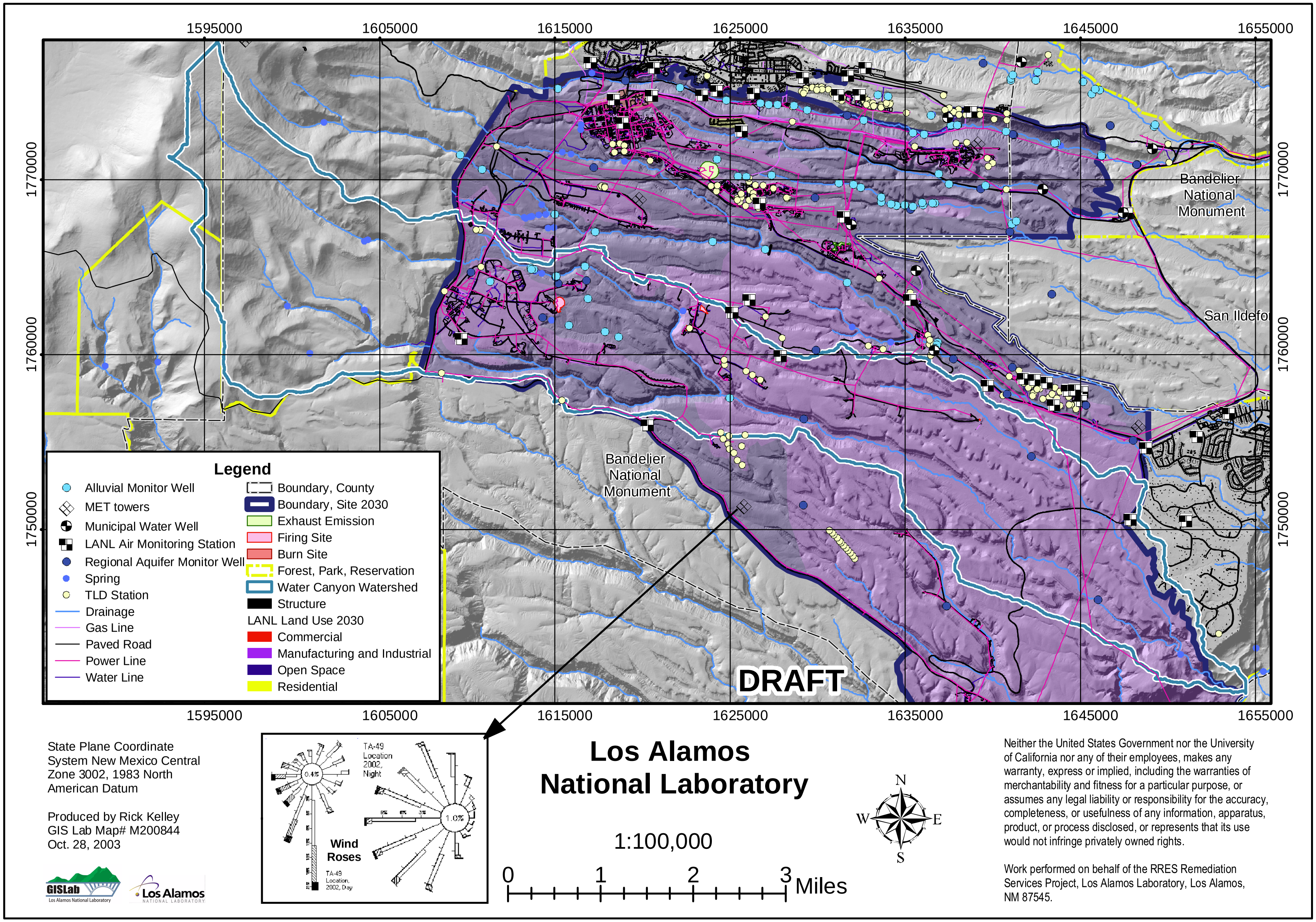


Figure 4.5b1. Hazard Area 5: Water Canyon Watershed, Hazard Category A: airborne releases, End state.

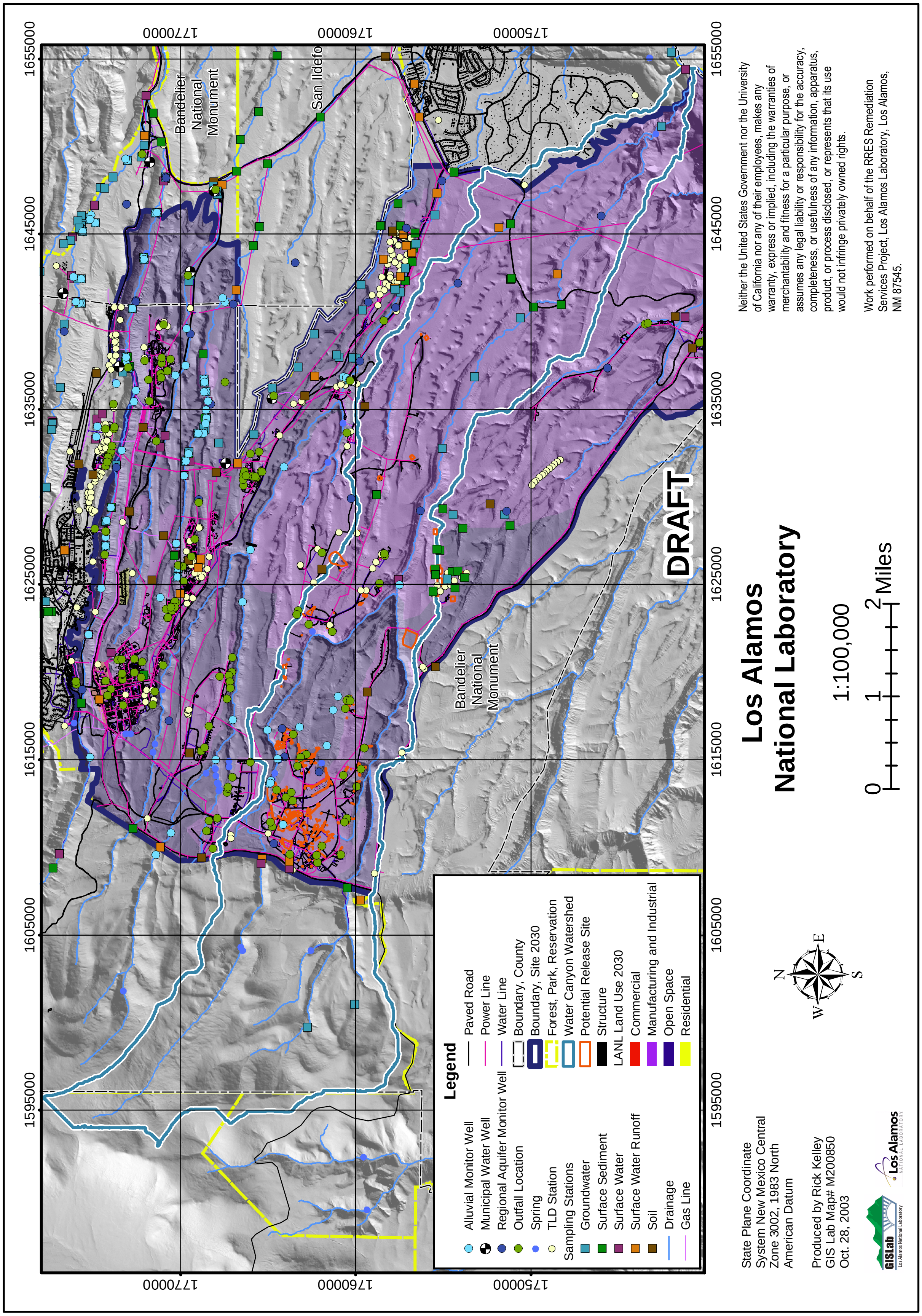


Figure 4.5b2. Hazard Area 5: Water Canyon Watershed, Hazard Category B: surface releases, End state.

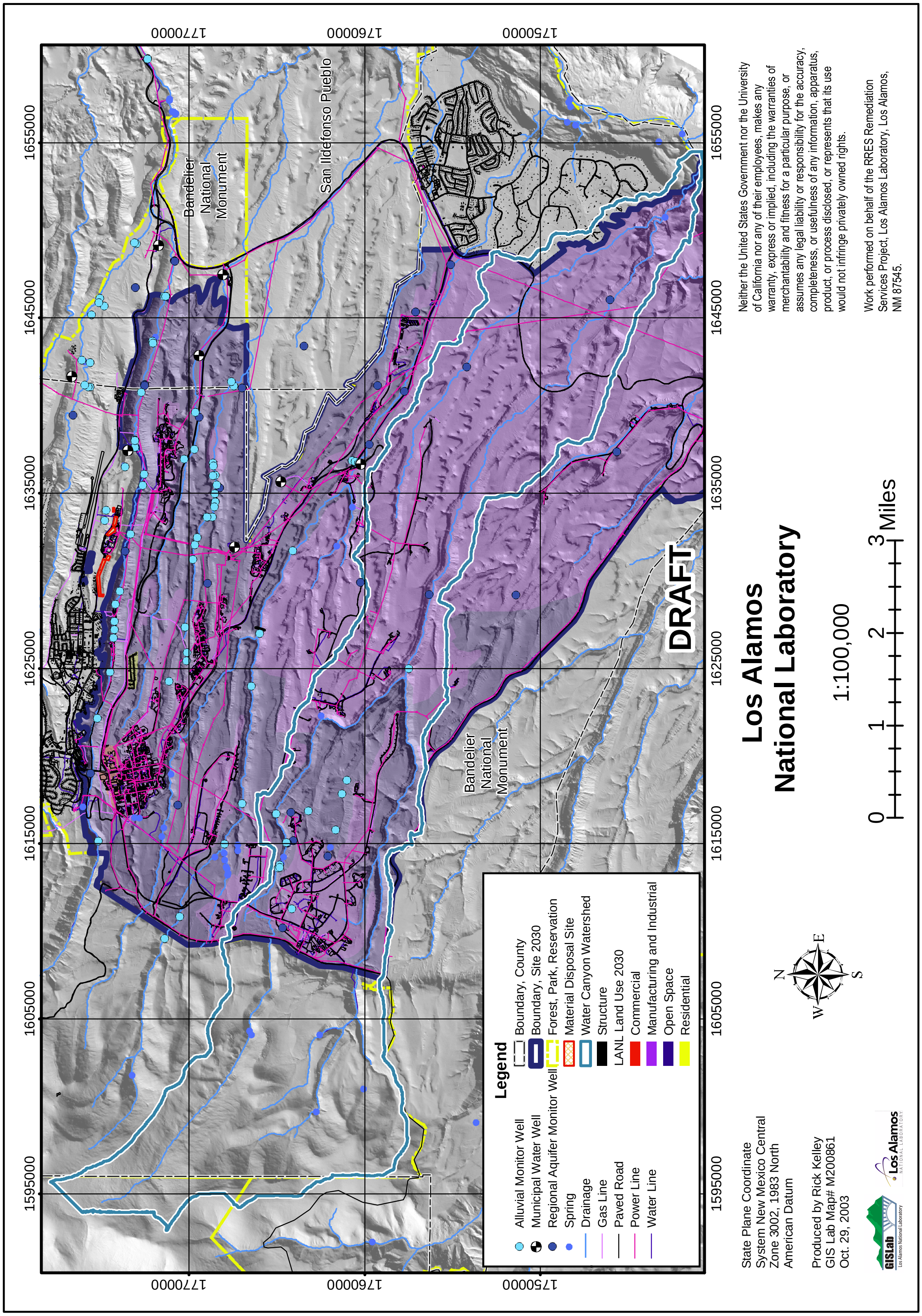


Figure 4.5b3. Hazard Area 5: Water Canyon Watershed, Hazard Category C: subsurface releases, End state.

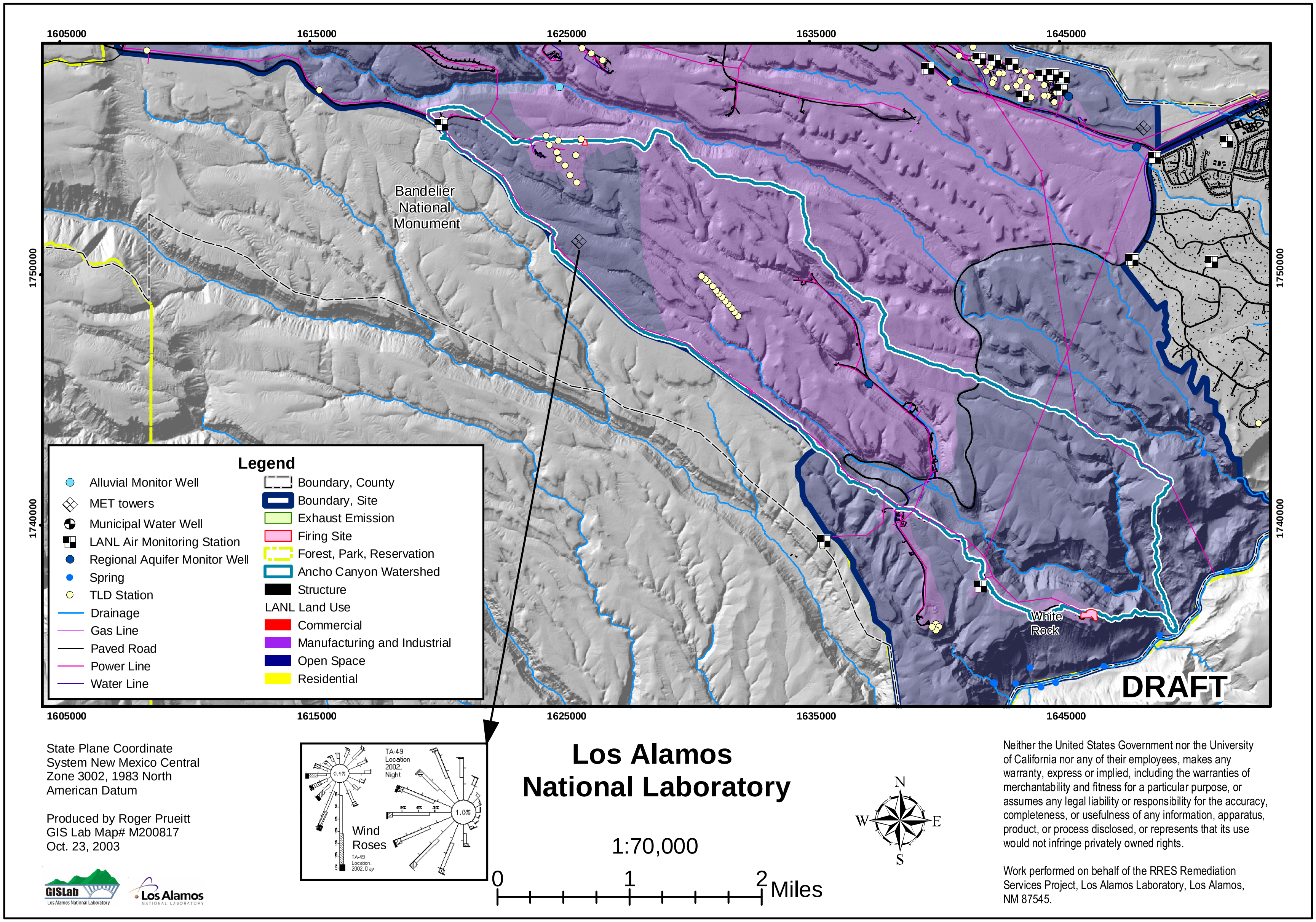


Figure 4.6a1. Hazard Area 4: Ancho Canyon Watershed, Hazard Category A: airborne releases, Current state.

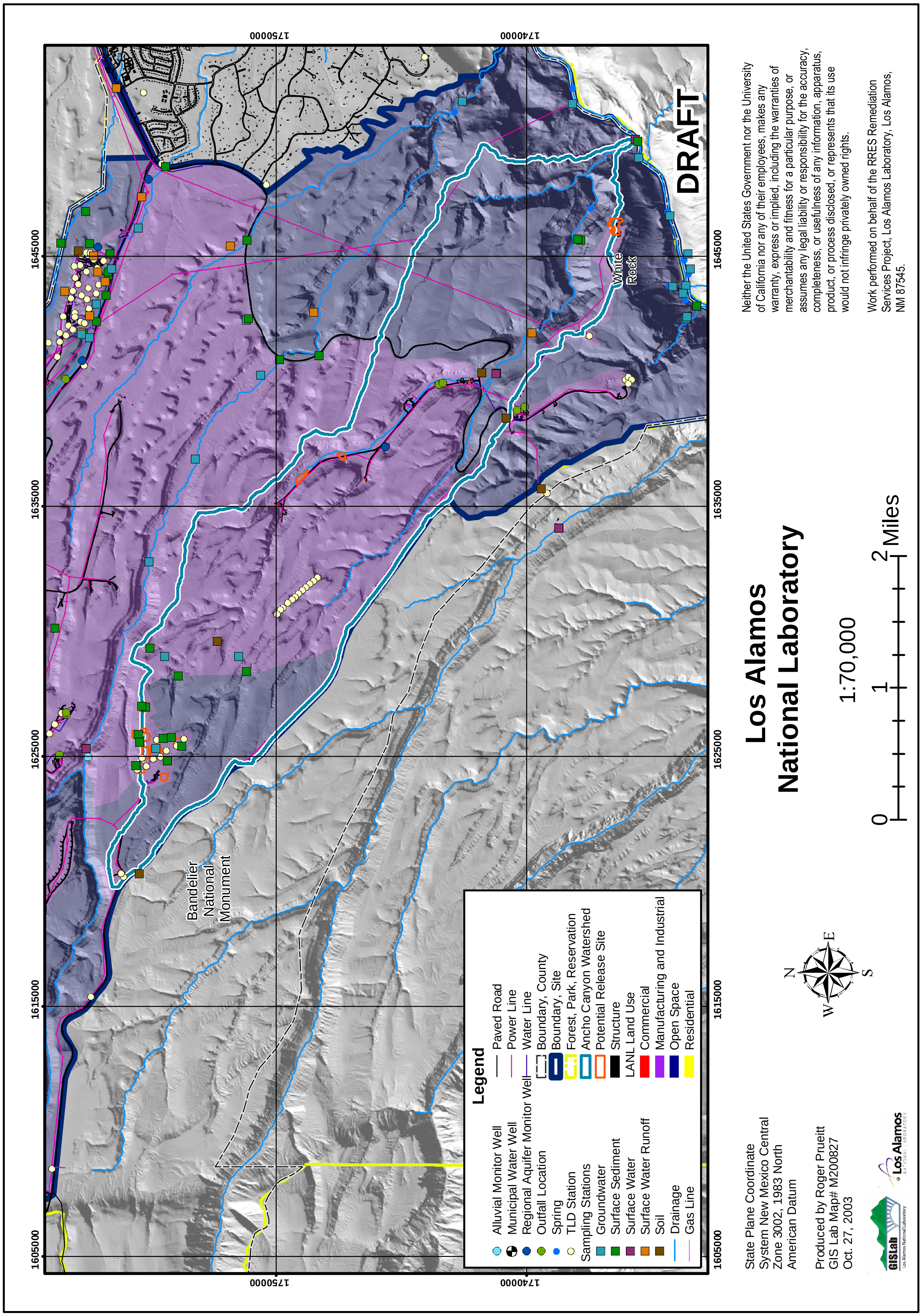


Figure 4.6a2. Hazard Area 6: Ancho Canyon Watershed, Hazard Category B: surface releases, Current state.

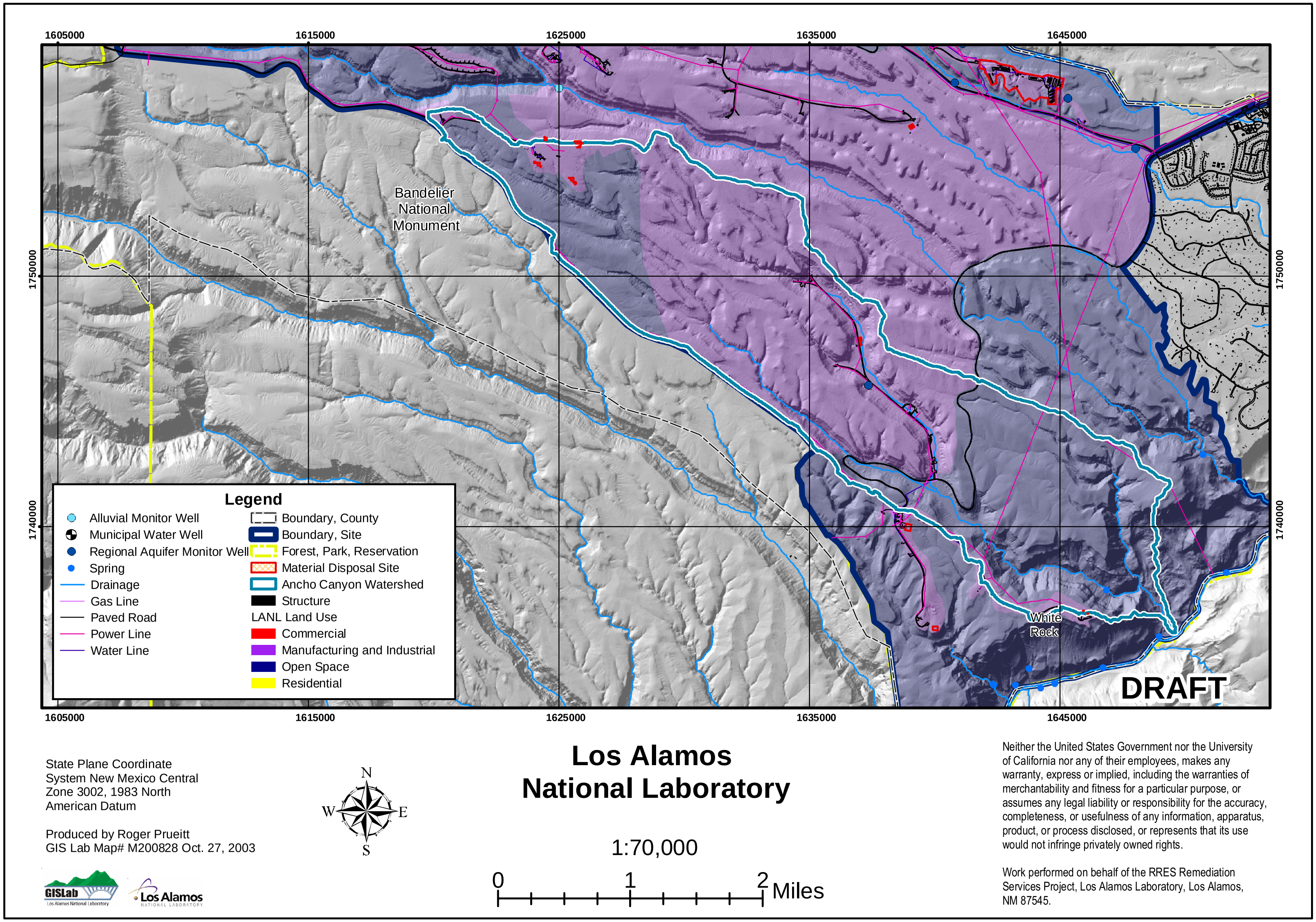


Figure 4.6a3. Hazard Area 6: Ancho Canyon Watershed, Hazard Category C: subsurface releases, Current state.

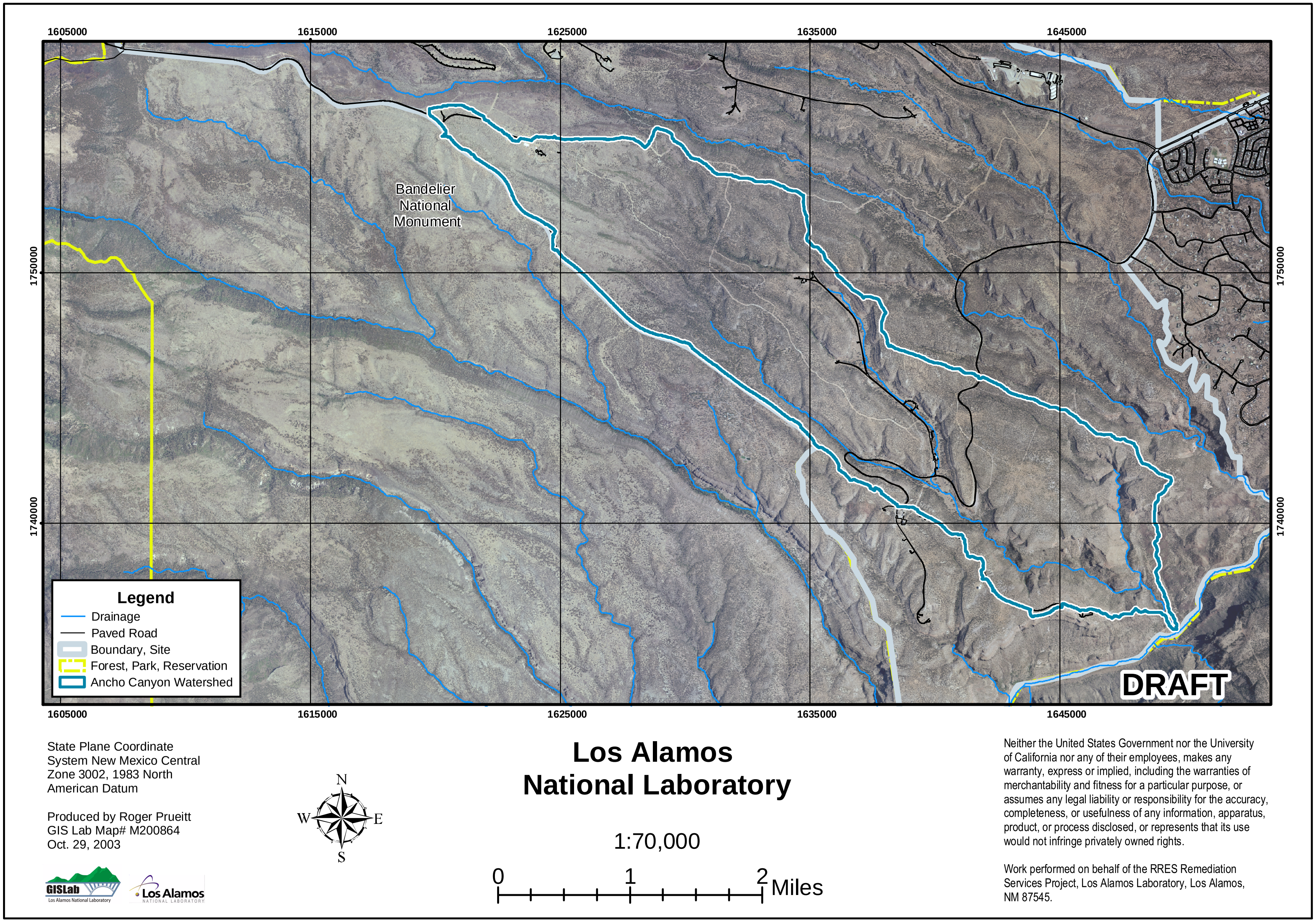


Figure 4.6a4. Hazard Area 6: Ancho Canyon Watershed orthophoto map.

de Valle watershed- largely production, experimentation, flashing, and disposal of explosives and explosives residues.

Referring to Figure 4.6a3, subsurface contamination in this watershed occurs in several subsurface MDAs. These are briefly discussed below, primarily to identify characteristics that provide some degree of exposure control, as identified in the conceptual site exposure model.

MDA D

MDA D is located at approximately 6500-ft (1950 m) elevation on a mesa. The depth to groundwater beneath MDA D is approximately 910 ft (273 m). MDA D consists of two underground chambers used to test explosive devices. The chambers were constructed in 1948 for initiator tests involving polonium-210, milligram quantities of beryllium, and large amounts of HE. One chamber was destroyed during testing. Debris from the detonation was ejected through the elevator shaft and spread over the mesa. A 10-ft-deep crater that formed around the chamber was later filled with the ejected debris and covered with uncontaminated soil.

MDA Y

MDA Y was one of several pits used for disposing of waste consisting primarily of debris from firing site experiments, empty chemical containers, and office waste. MDA Y was the first disposal pit at TA-39 and was used from 1973 until approximately 1976, when pit 2 was put in use. The depth to groundwater below MDA Y is approximately 590 ft (177 m).

MDA AB

MDA AB is located at an elevation on a high mesa within the Ancho Canyon watershed. The depth to groundwater below MDA AB is approximately 1120 ft (336 m). MDA AB was the location of the hydronuclear and related experiments performed from late 1959 to mid-1961. The experiments were conducted to assess safety of the storage and transportation of nuclear weapons components. The experiments were conducted in multiple shafts and chambers at depths between 60 ft and 80 ft (18 m to 24 m). The total volume of contaminated tuff has been estimated at about 1,000,000 ft^3 (30,000 m^3). The radiological inventory has been estimated as 0.2 Ci uranium-235 and 2,450 Ci plutonium-239, with some fission and activation products also likely to be present. Solid lead used as shielding as well as small amounts of beryllium are also contained in the experiment chambers. The experimental shafts were installed in four different areas in what are now, roughly, the corners of MDA AB. In 1961, the surface over the shafts in Area 2 was covered with a clay/gravel layer overlain with asphalt to stabilize residual surface contamination. This pavement was removed in 1999 as part of an interim measure (IM) of the RFI to protect the site from subsurface moisture that results from surface water ponding, run-on, and inhibited evapotranspiration. The IM was completed by installing a clean, crushed-tuff cap containing a wire-mesh layer to inhibit burrowing animals. It was covered with native grasses to promote transpiration of moisture and inhibit erosion, and gravel also to inhibit erosion.

4.6.2 Risk-Based End State

Figures 4.6b1, 4.6b2, and 4.6b3 present maps for airborne, surface, and subsurface contamination in the Water/Canon de Valle watershed, consistent with the risk-based end state vision in 2035. Continued use of this watershed for NNSA mission-critical experimental operations is expected through 2035, as suggested by the similarity in the current- and risk-based end-state maps. Surface contamination is expected to be removed as necessary to achieve risk-based levels consistent with the planned land use (either industrial or recreational). MDAs are expected to be capped and monitored to achieve risk-levels consistent with industrial use and transferred to NNSA.

4.7 Hazard Area 7: Chaquehui Watershed

The Chaquehui watershed heads on the plateau in the southeastern corner of the Laboratory has a drainage area of about 1.6 mi^2. It extends for about 3 mi, across LANL property and to its confluence with the Rio Grande.

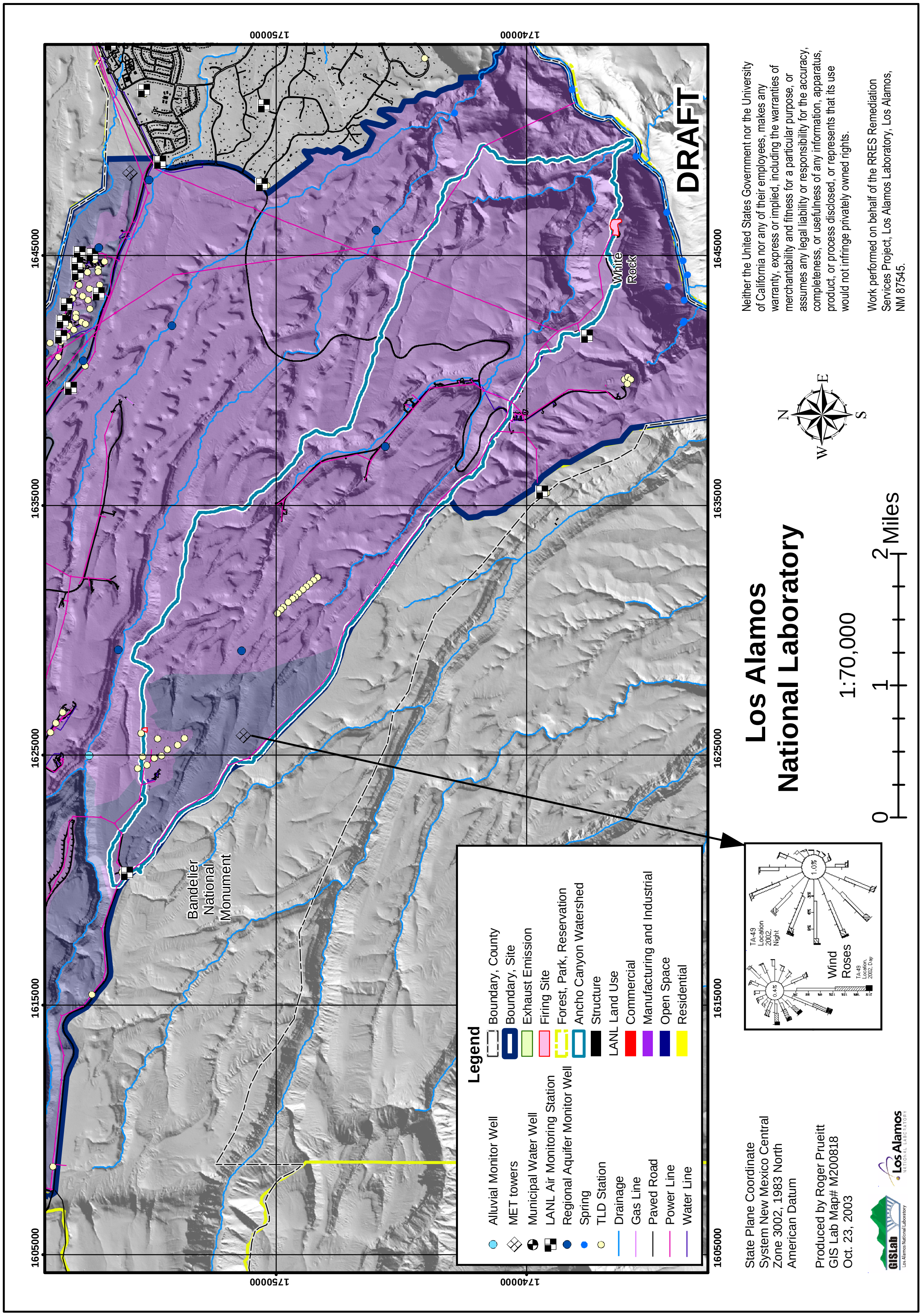


Figure 4.6b1. Hazard Area 6: Ancho Canyon Watershed, Hazard Category A: airborne releases, End state.

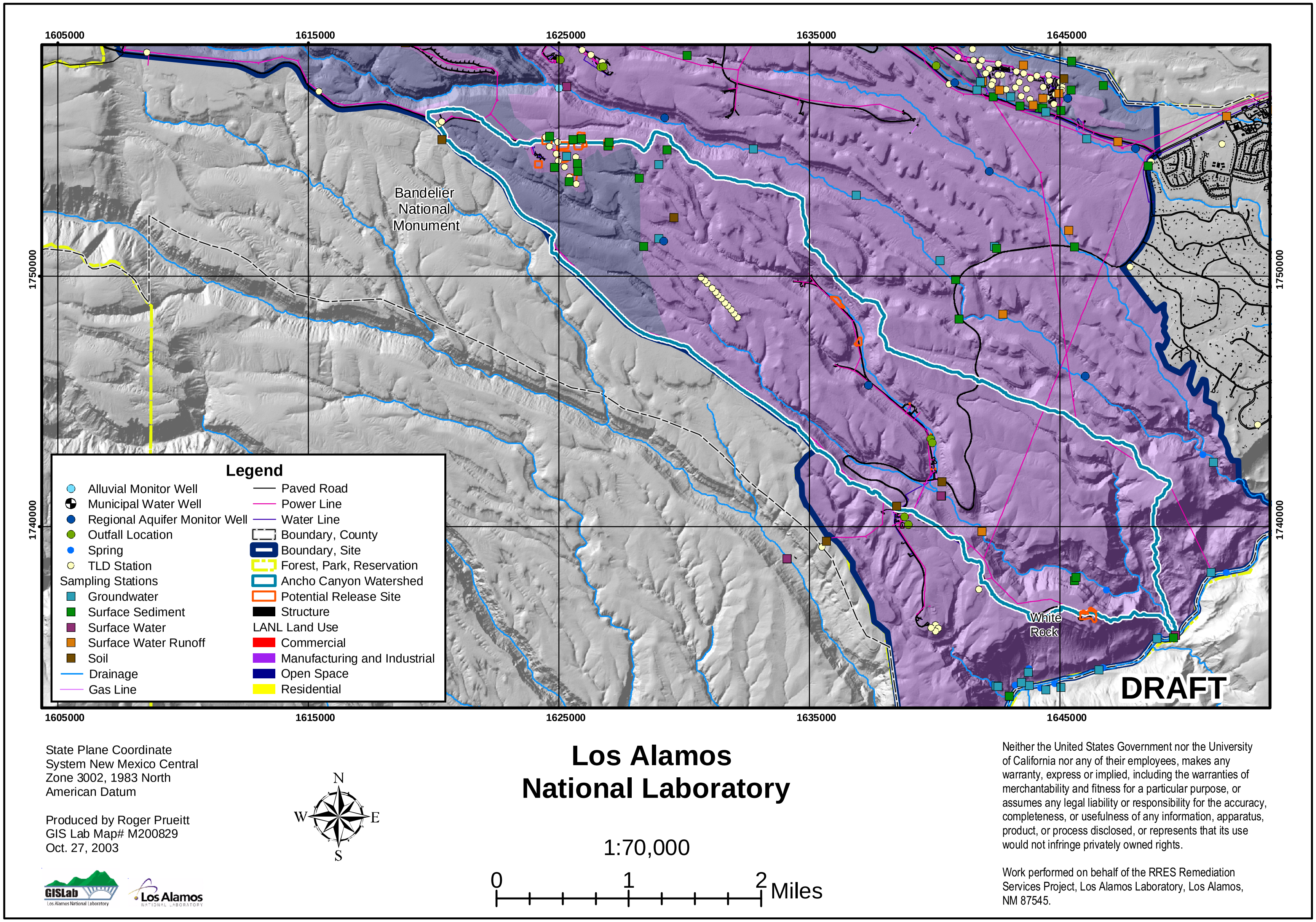


Figure 4.6b2. Hazard Area 6: Ancho Canyon Watershed, Hazard Category B: surface releases, End state.

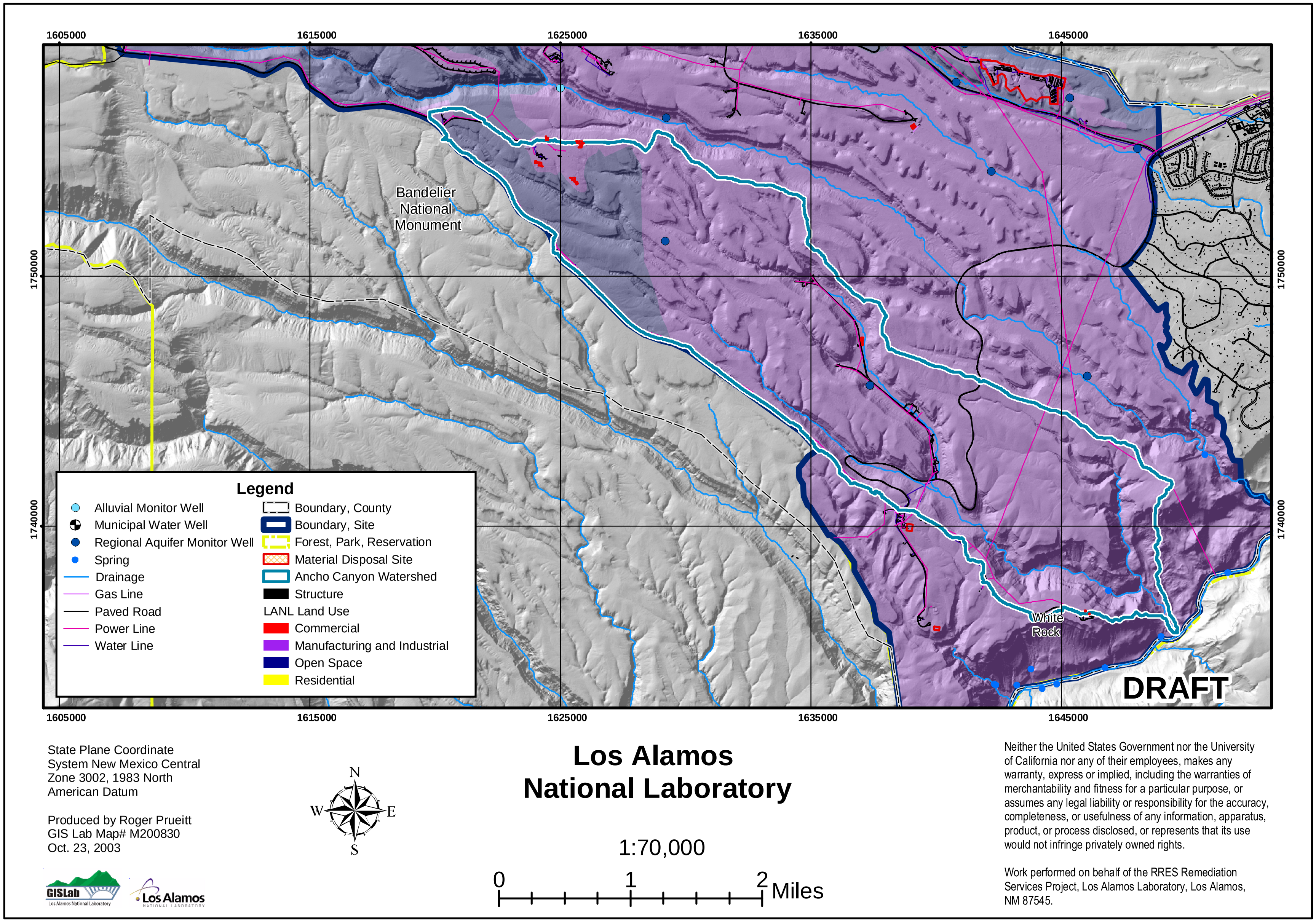


Figure 4.6b3. Hazard Area 6: Ancho Canyon Watershed, Hazard Category C: subsurface releases, End state.

Chaquehui Canyon is ephemeral all the way down to a point about 1/2 mi upstream from its confluence with the Rio Grande. At this point, a perennial spring, fed by the main aquifer, supports perennial flow for a short distance, followed by a short intermittent reach. About 1/4 mi upstream from the confluence with the Rio Grande, perennial spring water supports perennial flow that extends to the Rio Grande.

The sources of contamination in this watershed are firing sites. The US Forest Service previously owned the land.

Experiments involved testing of beryllium-containing initiators. Many experiments used uranium components. Polonium-210 was used as the radioactive source. With a half-life of 138 days, all polonium-210 has since decayed to undetectable levels.

A high-pressure tritium facility was operational at Main Site until late 1990.

The only LANL operations that discharge or drain directly into this watershed are the historical, inactive firing sites. Extremely low concentrations of tritium were detected during one sampling event in a spring in Chaquehui canyon; no other contamination issues are believed to exist.

4.7.1 Current State

Figures 4.7a1, 4.7a2, and 4.7a3 identify the airborne, surface and subsurface hazards. The only significant hazards in terms of inventory are associated with two relatively small MDAs.

MDA E

MDA E sits on mesa at approximately 6500-ft (1950 m) elevation. The depth to groundwater beneath MDA E is approximately 760 ft (228 m). MDA E operated between 1948 and 1955 for disposal of gun-type initiators and debris. Test material contaminated with polonium-210 was carried to the open pits. The first structure was underground chamber used for a single experiment in 1950. The explosive experiment in the chamber did not breach the surface. Beginning in 1951, a second site was used for gun-type and implosion studies, and for storage area and for burial of low-level radioactive contaminated equipment. Existing records indicate that the area contains several hundred kilograms of depleted uranium and some hazardous presence of hazardous waste

MDA K

MDA K is located on a mesa at an approximate elevation of 6500 ft (1950 m). The depth to groundwater beneath MDA K is approximately 820 ft (246 m). MDA K received liquid effluent from the high-pressure tritium facility that operated at from 1955 until 1990. This facility housed equipment used to transfer tritium from large tanks to smaller tanks that were transported to various LANL locations. After the tritium facility operations ceased in 1990, all equipment was removed from the building. The building and associated structures are scheduled for decontamination and decommissioning. MDA K contains a septic tank and drain field, sumps, a cooling water outfall, and a roof drain outfall.

4.7.2 Risk-Based End State

Figures 4.7b1, 4.7b2, and 4.7b3 identify the airborne, surface and subsurface hazards as they are expected under the conditions achieved by cleanup consistent with anticipated land use, which is generally industrial/recreational under LANL management.

4.8 Hazard Area 8: Frijoles Watershed

Frijoles watershed heads in the Sierra de los Valles on US Forest Service lands, and extends in a southeasterly direction across US Park Service land for about 14 mi to its confluence with the Rio Grande. The canyon remains on Bandelier National Monument grounds for most of its extent, and intersects LANL property for only a very short distance. Its drainage area is approximately 19 sq. mi.

A small perennial stream originates from springs and seeps in upper Frijoles canyon; two other springs produce surface flow that extends to the Rio Grande confluence.

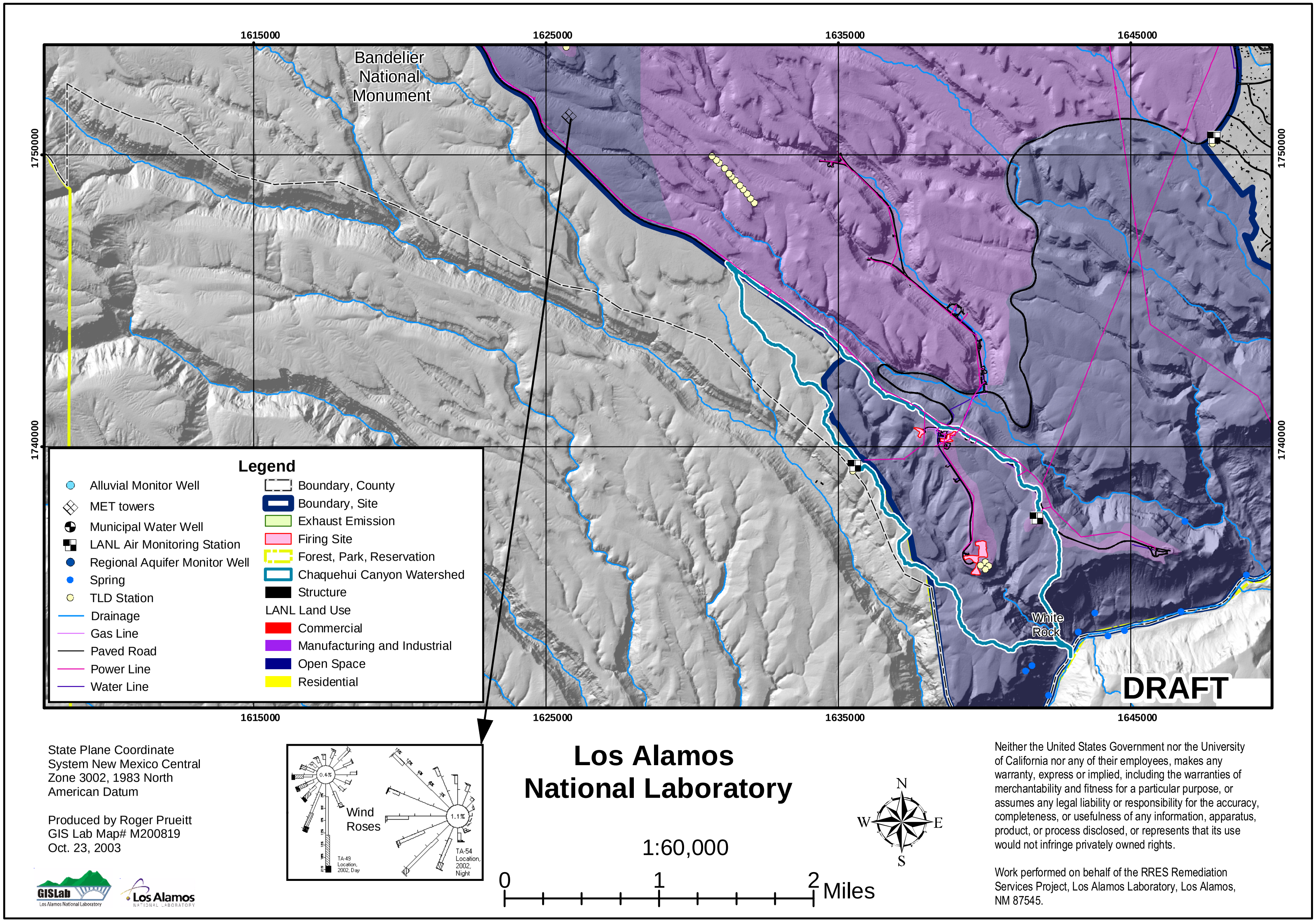


Figure 4.7a1. Hazard Area 7: Chaquehui Canyon Watershed, Hazard Category A: airborne releases, Current state.

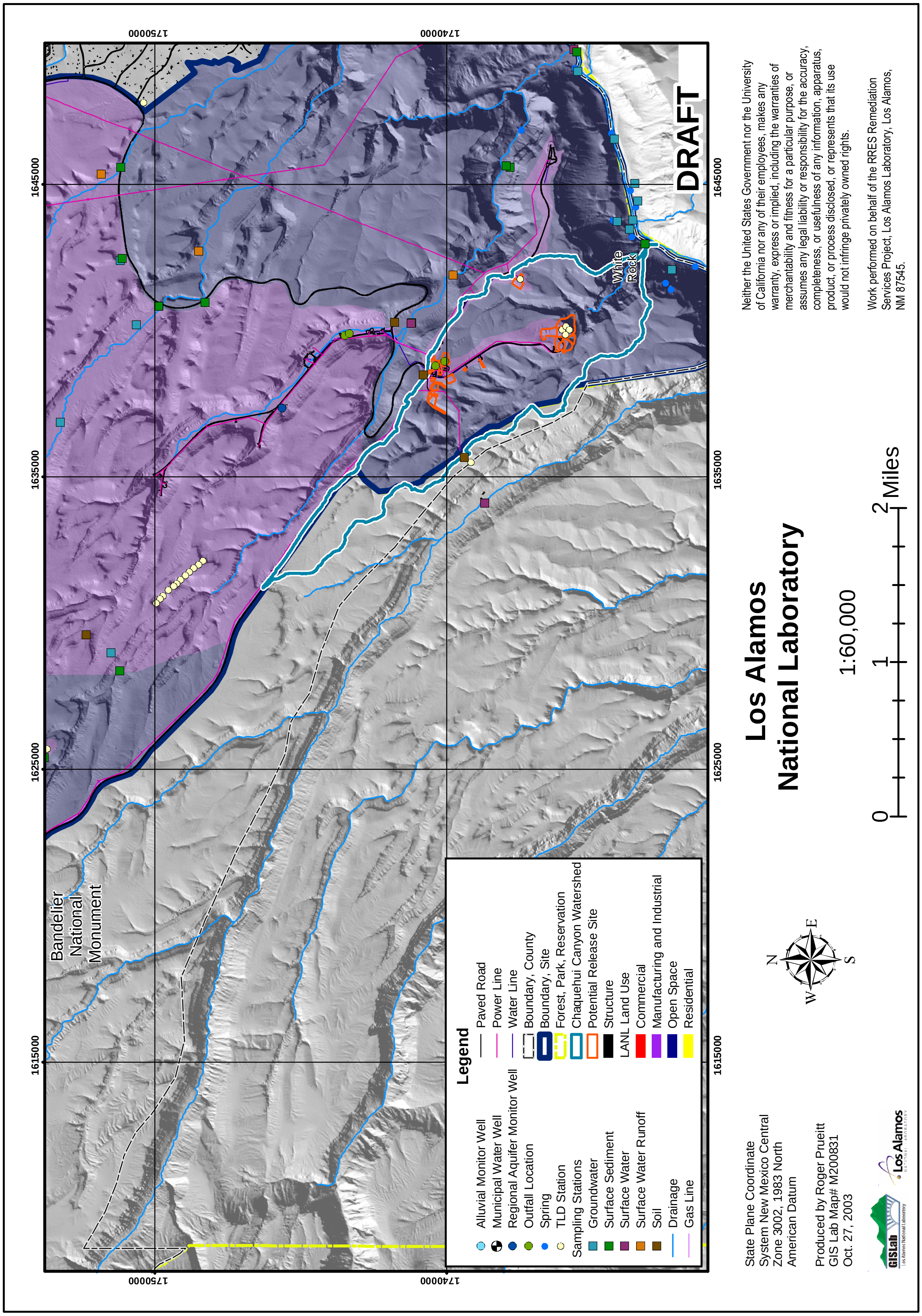


Figure 4.7a2. Hazard Area 7: Chaquehui Canyon Watershed, Hazard Category B: surface releases, Current state.

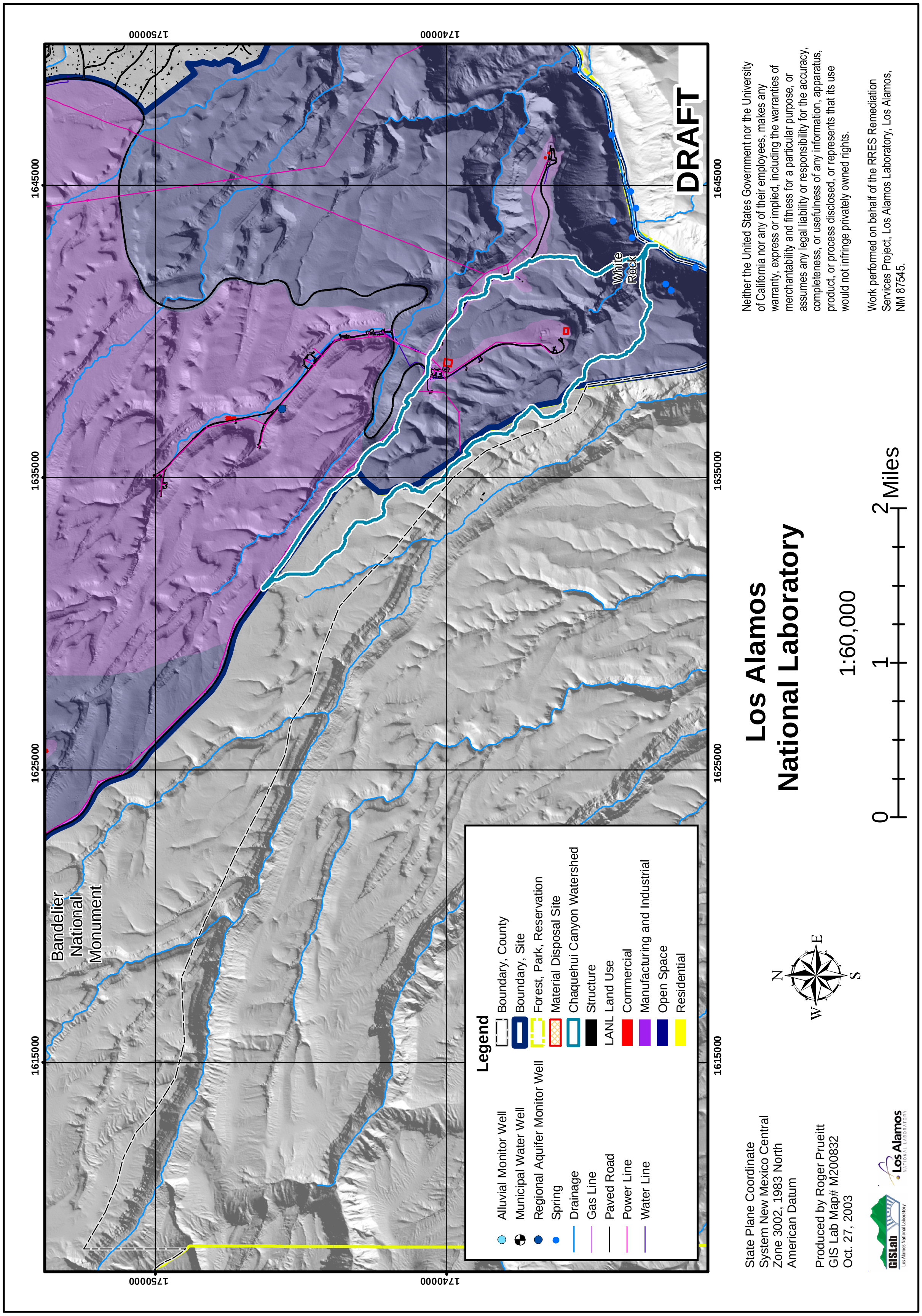


Figure 4.7a3. Hazard Area 7: Chaquehui Canyon Watershed, Hazard Category C: subsurface releases, Current state.

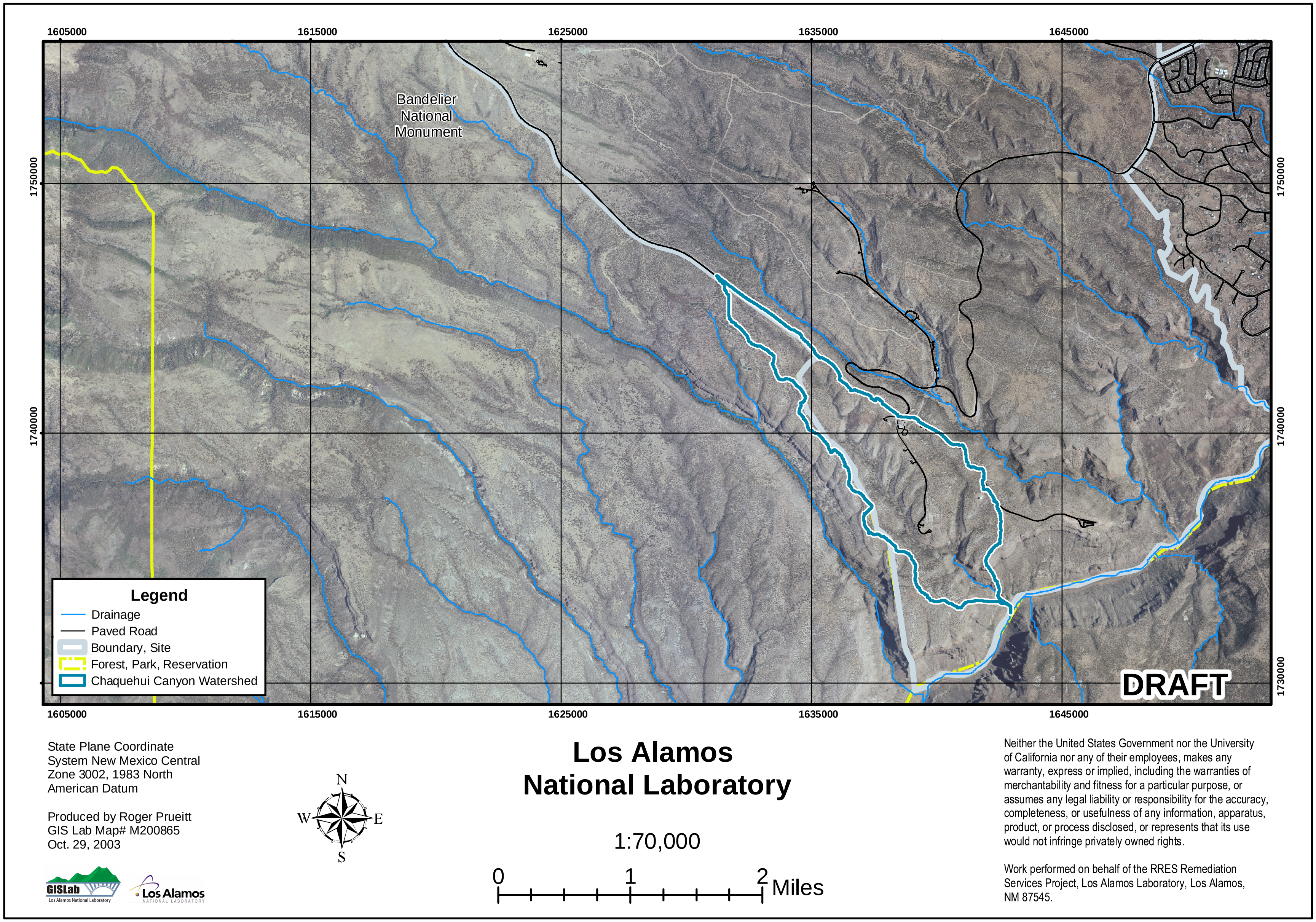


Figure 4.7a4. Hazard Area 7: Chaquehui Canyon Watershed orthophoto map.

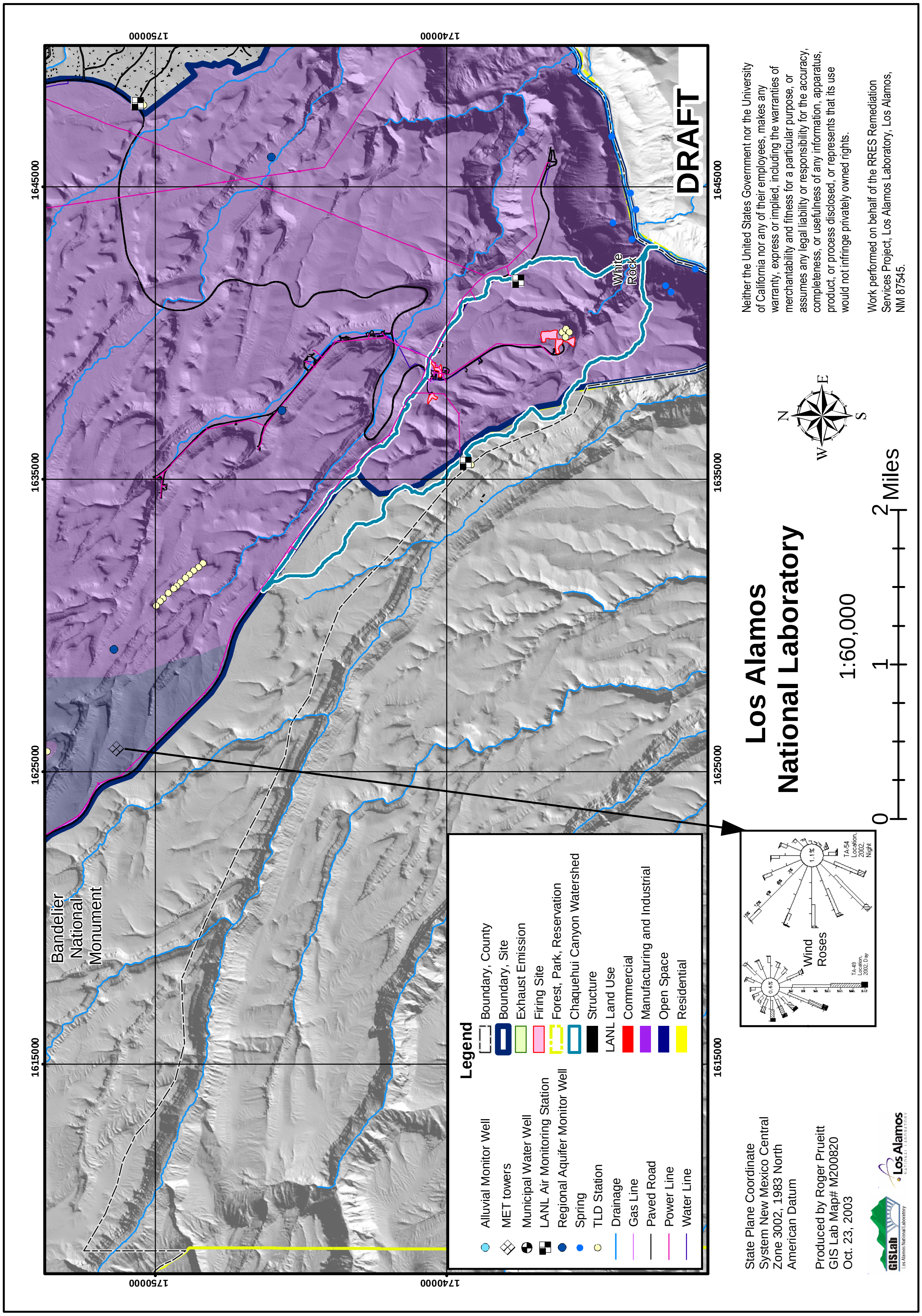


Figure 4.7b1. Hazard Area 7: Chaquehui Canyon Watershed, Hazard Category A: airborne releases, End state.

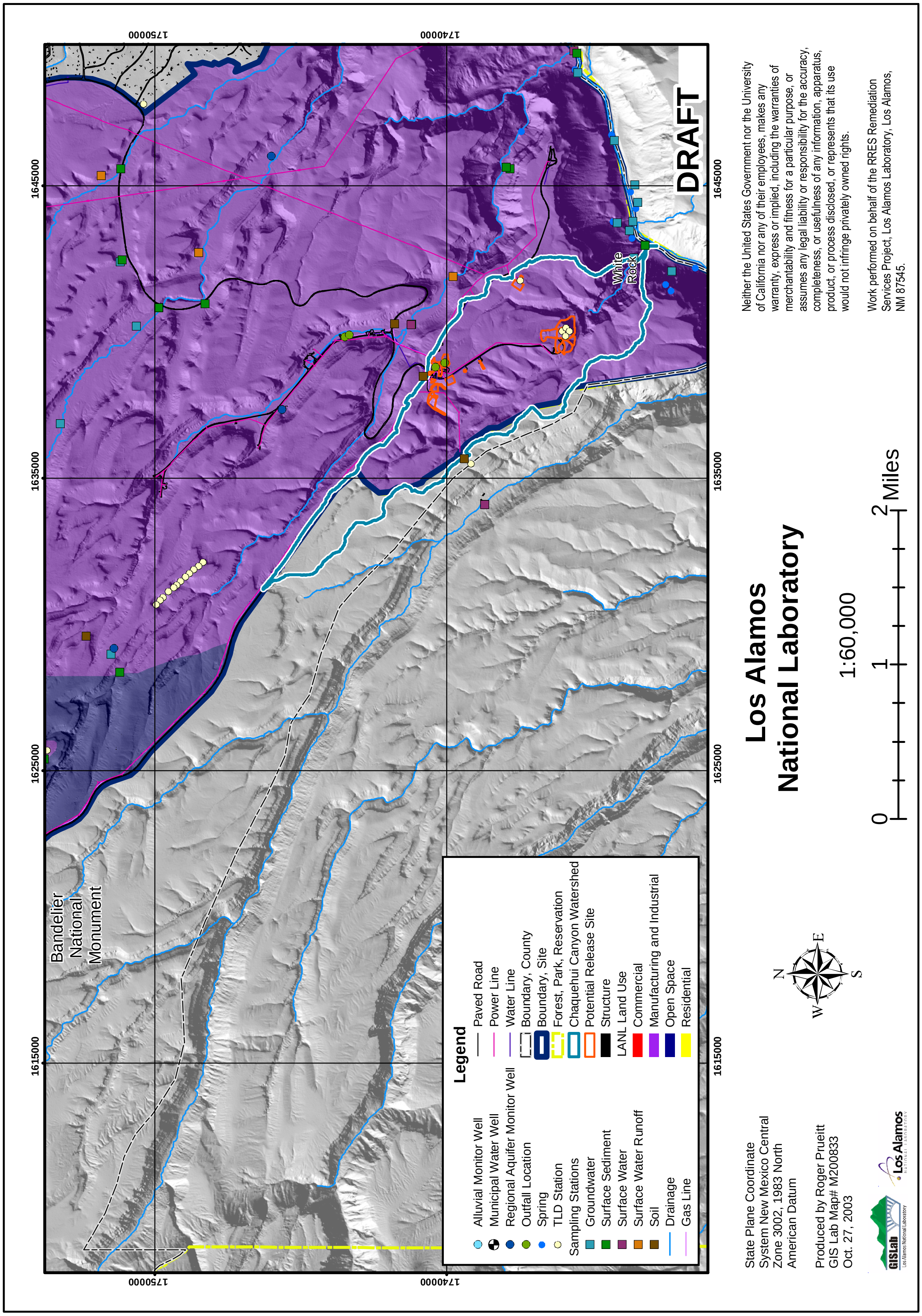


Figure 4.7b2. Hazard Area 7: Chaquehui Canyon Watershed, Hazard Category B: surface releases, End state.

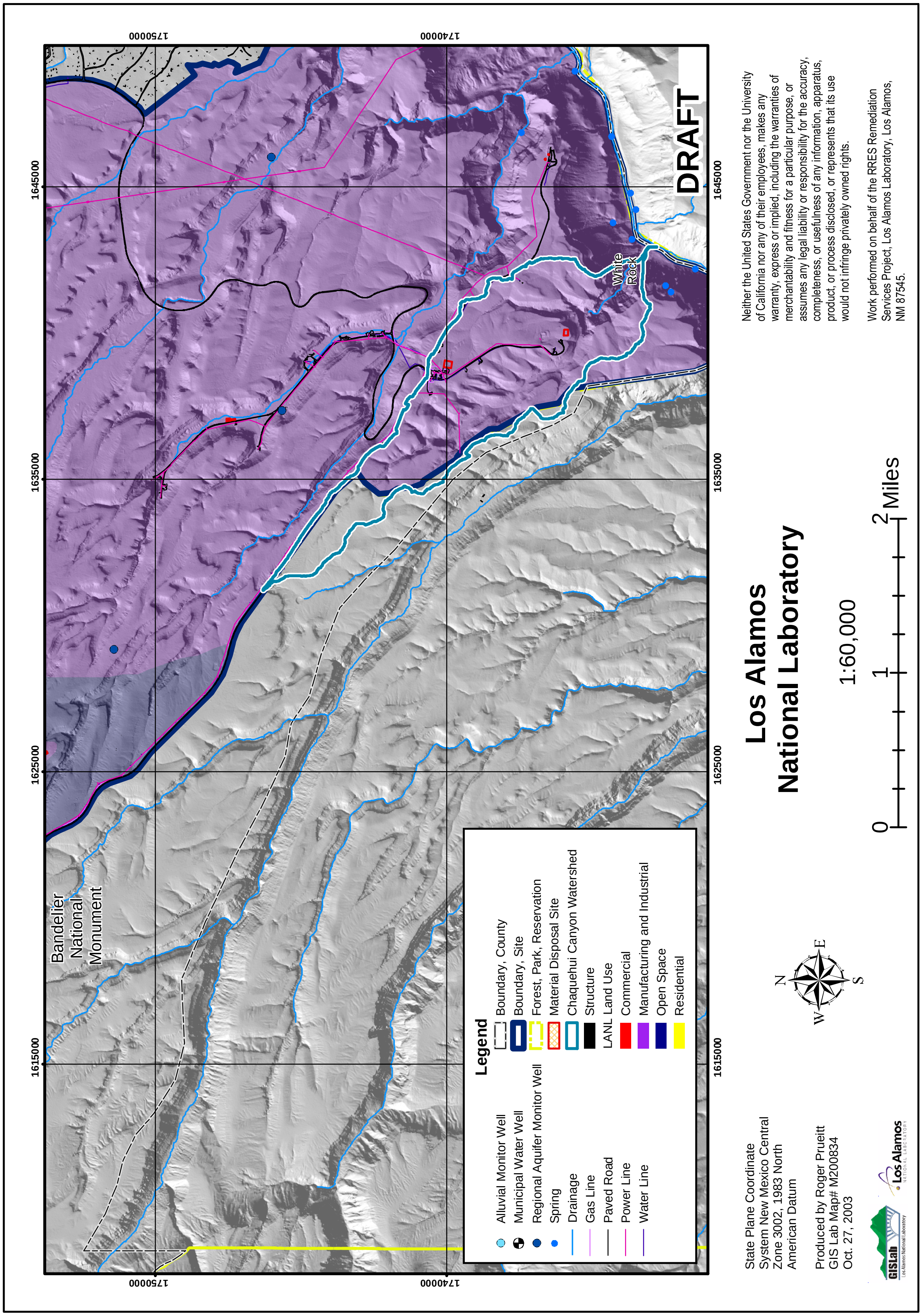


Figure 4.7b3. Hazard Area 7: Chaquehui Canyon Watershed, Hazard Category C: subsurface releases, End state.

No Laboratory operations have either historically or currently drain or discharge into the Frijoles watershed. It is of particular interest, however, because it crosses Bandelier National Monument lands, which are administered by the National Park Service and used extensively for recreational purposes.

4.8.1 Current State

The current-state hazard-specific maps for Frijoles watershed are provided in Figures 4.8a1, 4.8a2, and 4.8a3. Conceptual site models are not included due to the very low level of hazards.

4.8.2 Risk-Based End State

Referring to the risk-based end state maps for Frijoles canyon shown in Figure 4.8b1, 4.8b2, and 4.8b3, cleanup actions will be completed to ensure that risks are acceptable under recreational-use scenarios. Portions of Frijoles canyon are expected to be returned to the National Forest Service or the National Park Service.

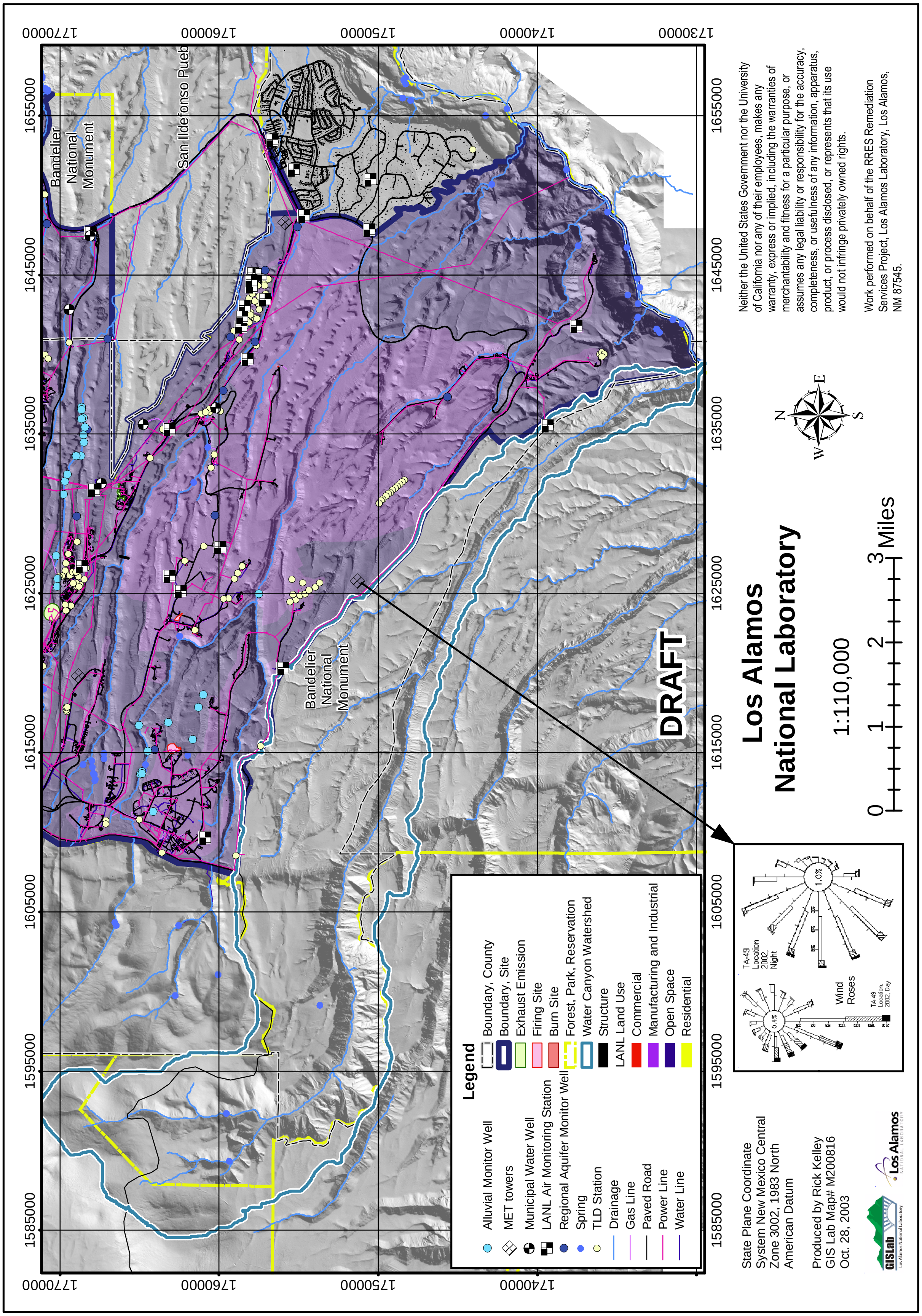


Figure 4.8a1. Hazard Area 8: Frijoles Canyon Watershed, Hazard Category A: airborne releases, Current state.

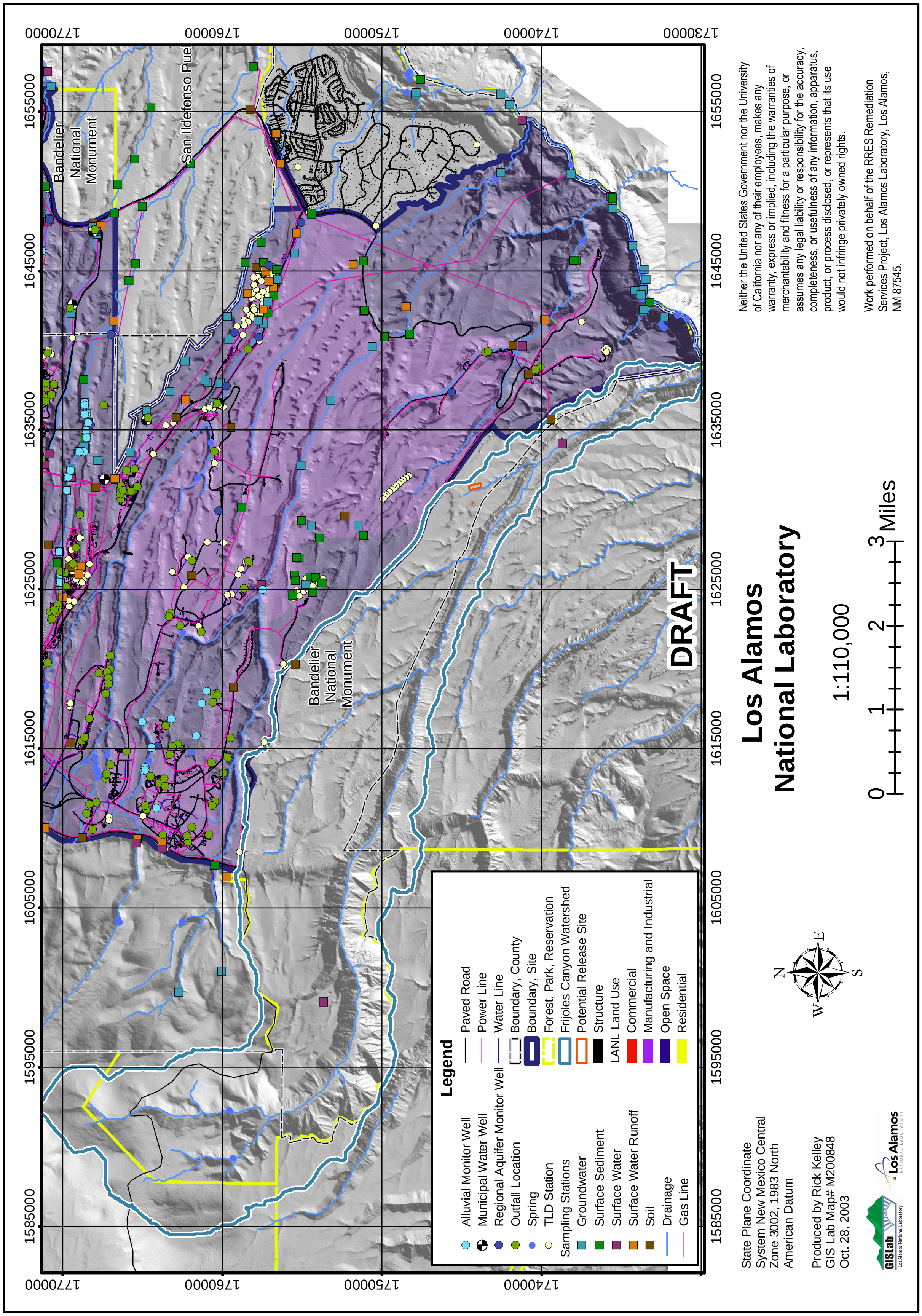


Figure 4.8a2. Frijoles Canyon Watershed, Hazard Category B: surface releases, Current state.

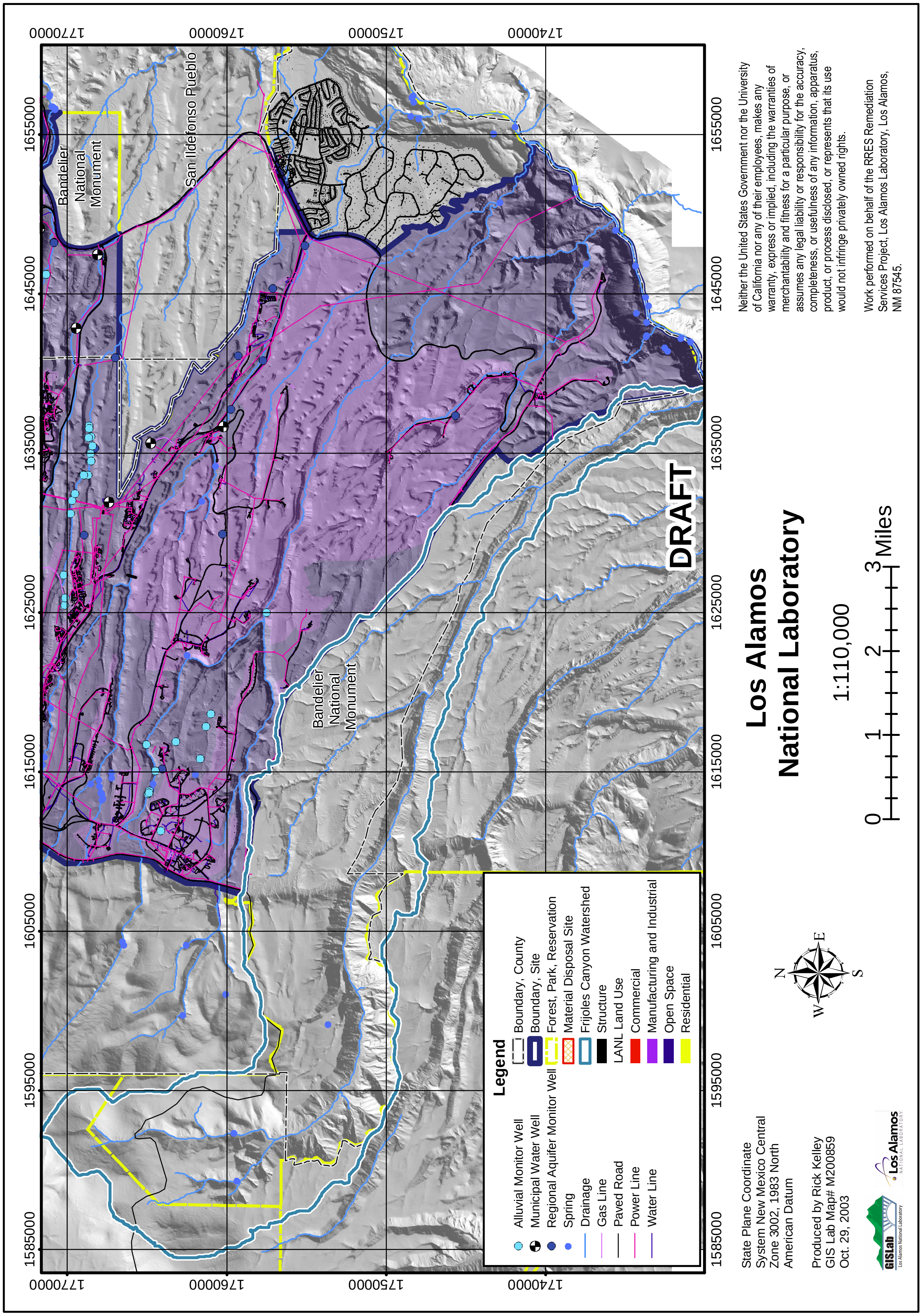


Figure 4.8a3. Hazard Area 8: Frijoles Canyon Watershed, Hazard Category C: subsurface releases, Current state.

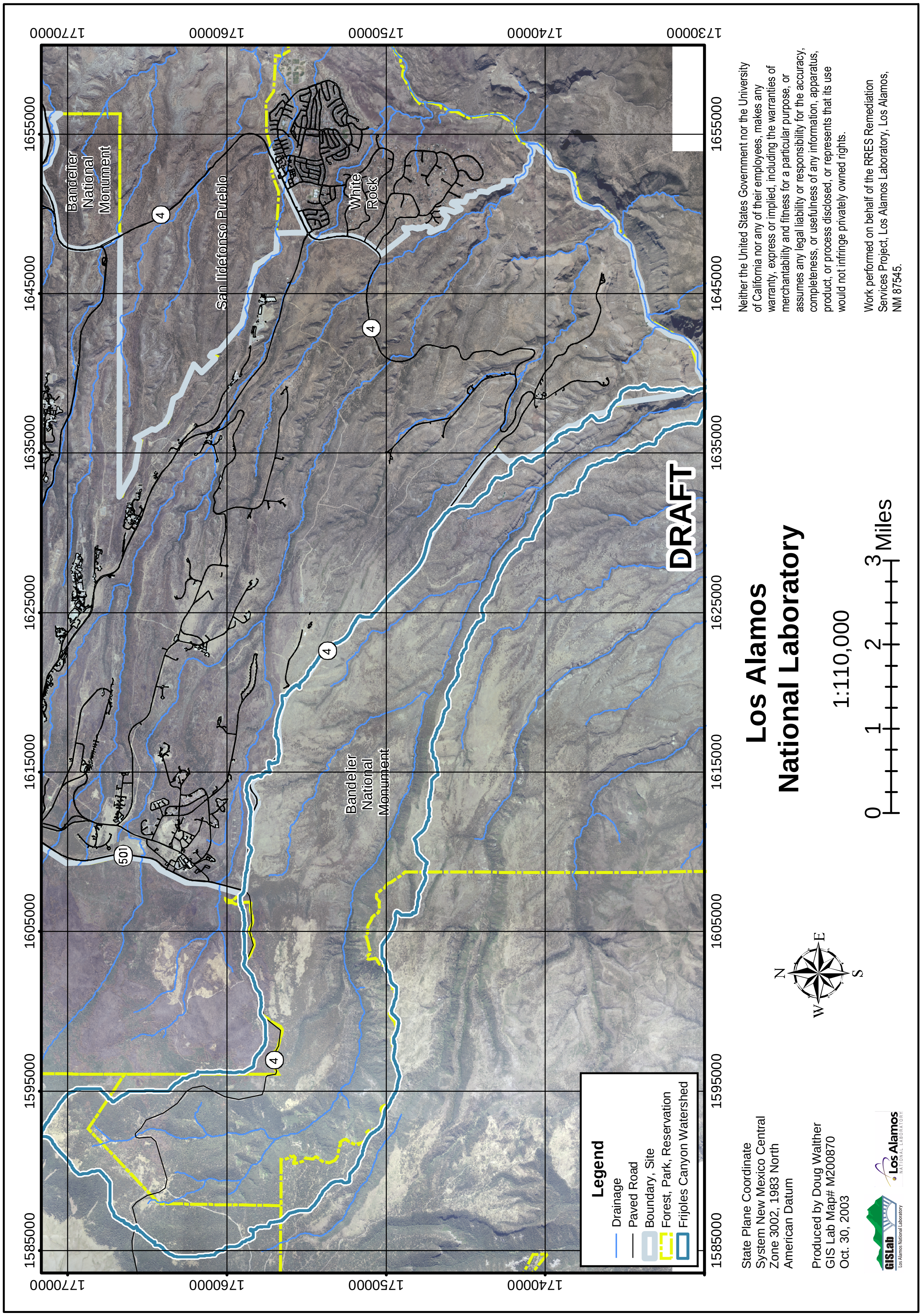


Figure 4.8a4. Hazard Area 8: Frijoles Canyon Watershed orthophoto map.

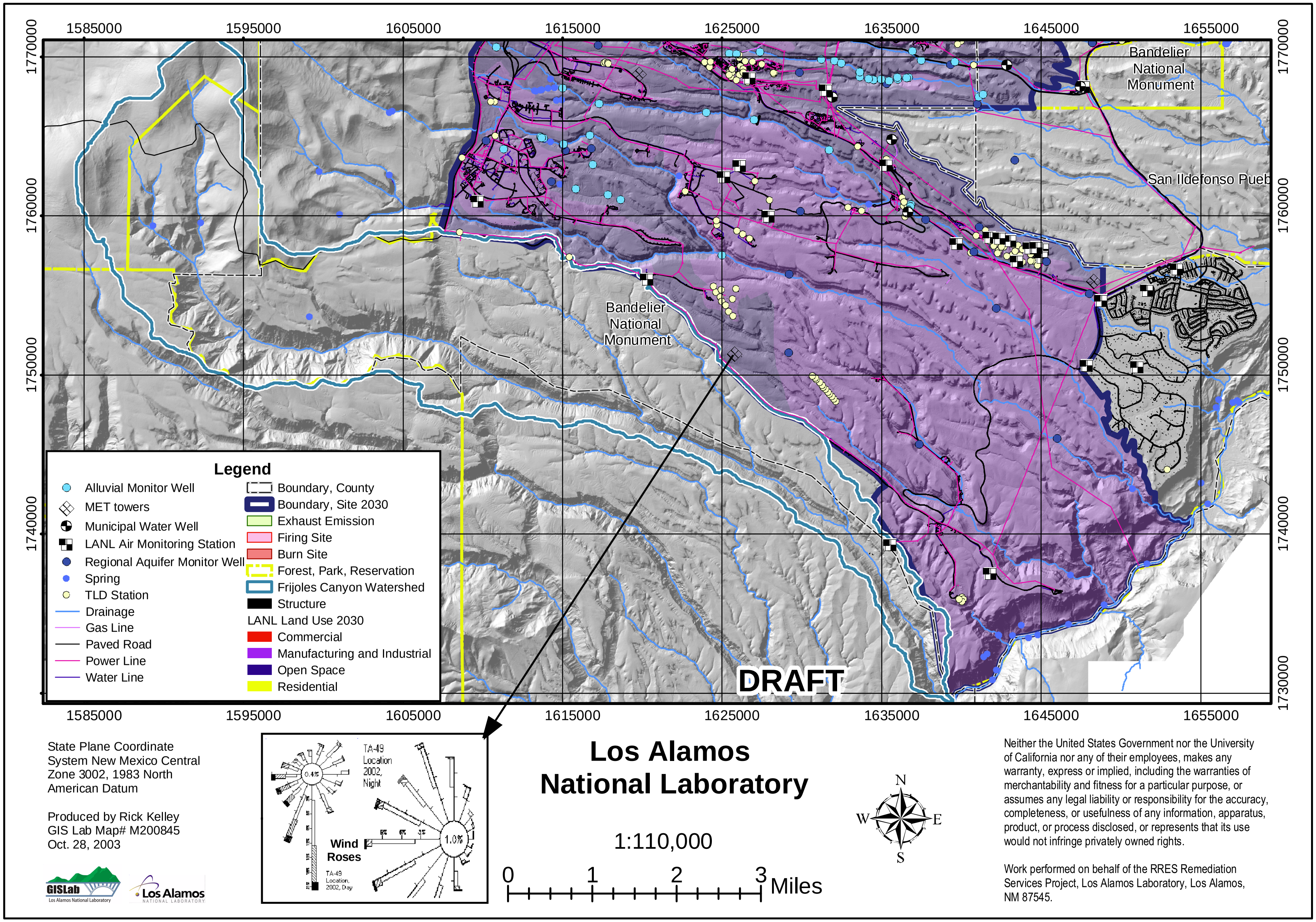


Figure 4.8b1. Hazard Area 8: Frijoles Canyon Watershed, Hazard Category A: airborne releases, End state.

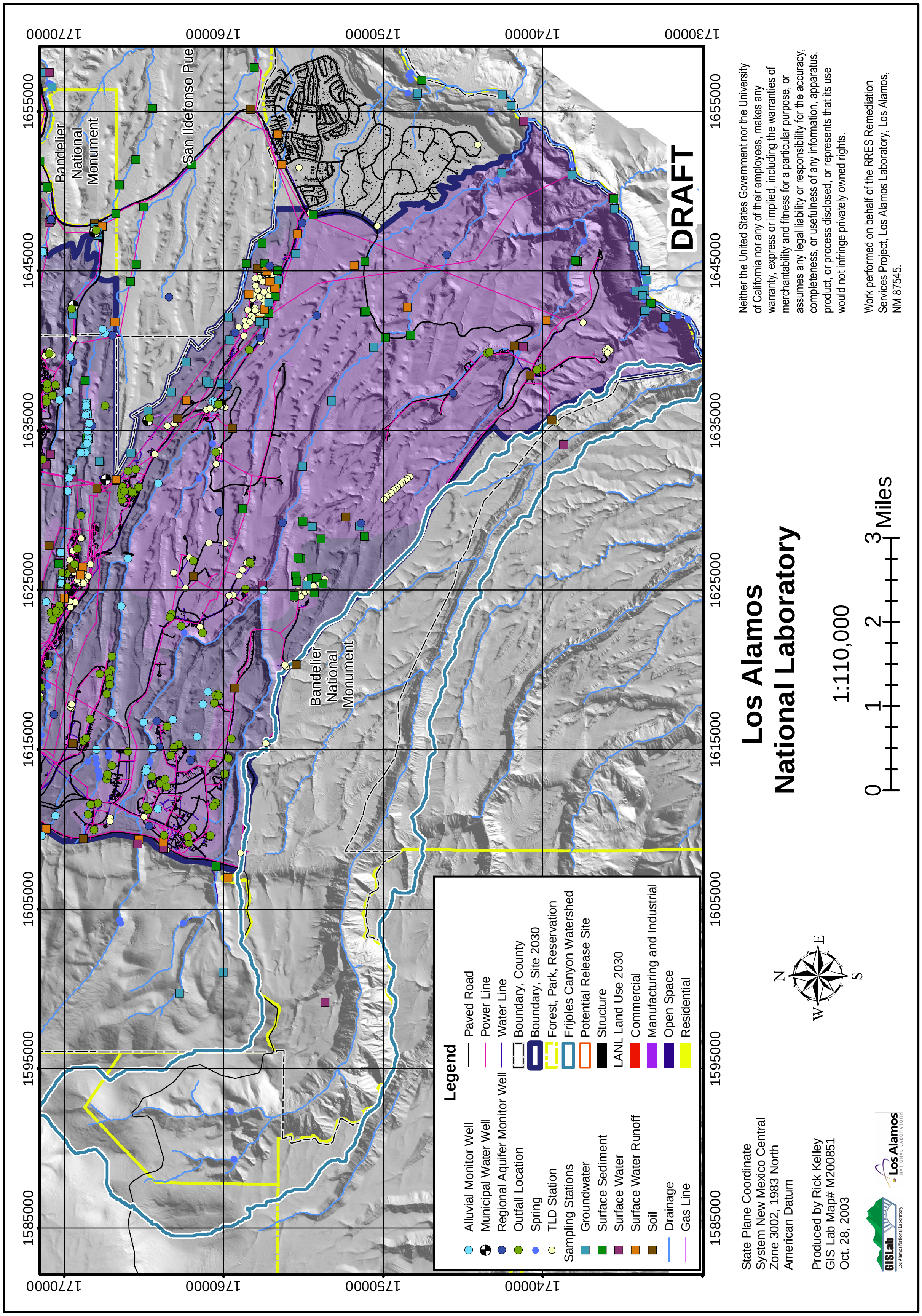


Figure 4.8b2. Hazard Area 8: Frijoles Canyon Watershed, Hazard Category B: surface releases, End state.

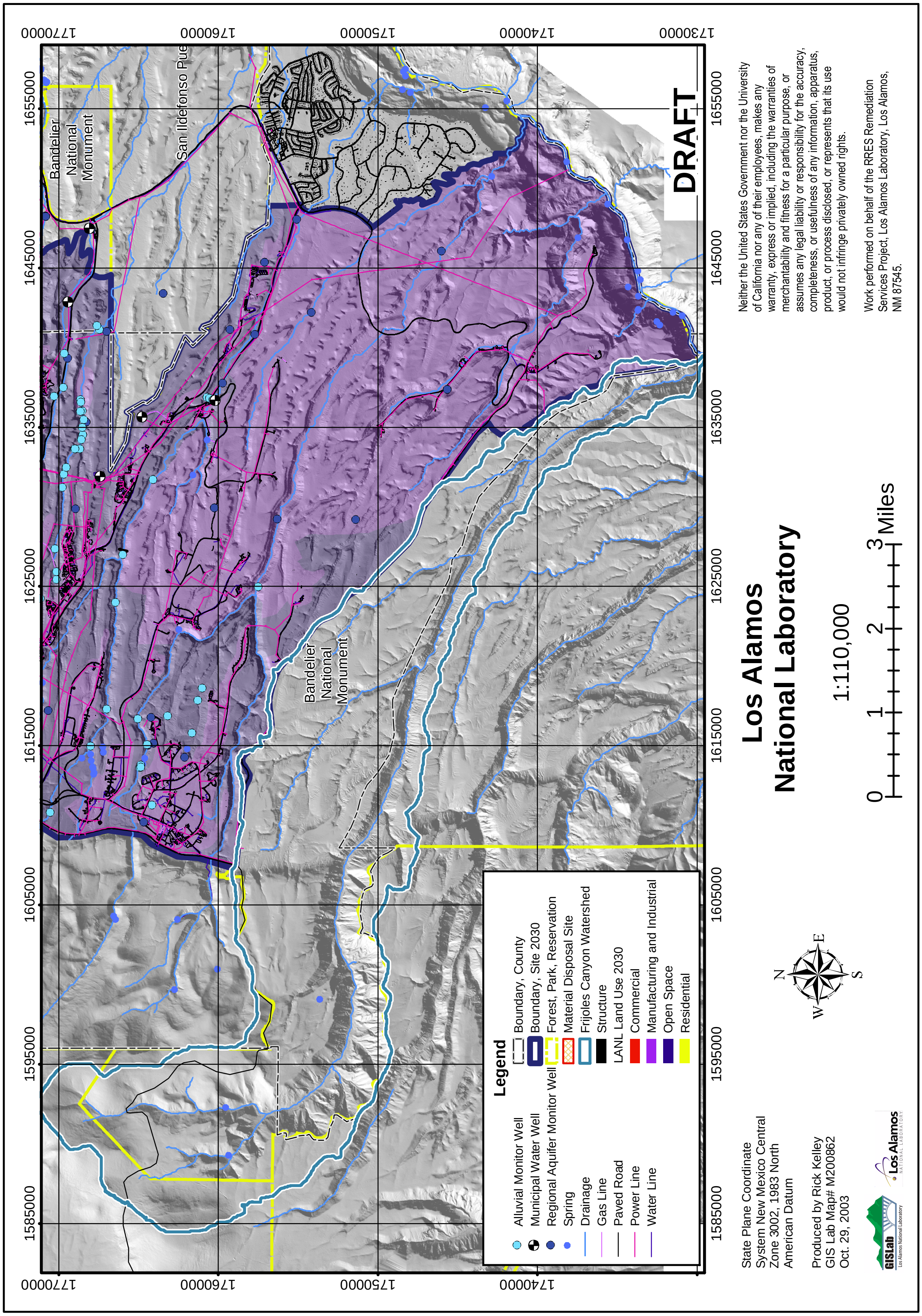


Figure 4.8b3. Hazard Area 8: Frijoles Canyon Watershed, Hazard Category C: subsurface releases, End state.

Risk-Based End States: Variance Appendix

There are no known variances between the Risk-Based End State (RBES) Vision and the baseline or regulatory documents. However, new information or regulatory direction could create variances. This appendix describes the assumptions used for the RBES Vision, the potential variances that could result from changes to these assumptions, and the risk of those changes.

The working LANL baseline contains the assumptions upon which the RBES Vision is based. These assumptions include appropriate land use for industrial mesa top areas, presumptive remedy of covers in place for all major Material Disposal Areas, no large clean ups in canyon areas or groundwater, and prioritization of sites—at both watershed and aggregate scale—based on risk (high risk sites addressed first). Some sites identified as potential release sites in the EM program are still being used for National Nuclear Security Administration (NNSA) operations and mission (for example, firing sites) and can not be remediated until NNSA no longer needs these sites for its mission. These sites are termed “active sites.” The RBES Vision assumes that active sites will not have been remediated at the end state. The assumption is that NNSA would remediate the sites when activities cease at them at some unknown future date. The baseline matches the commitments of the Performance Management (PMP) Strategy, most notably to complete ten MDAs by 2010, all sites in Los Alamos/Pueblo watershed by 2010, and all EM sites by 2015.

Further information or change in regulatory direction may lead to potential variances in the assumptions upon which the RBES Vision is based. These variances, and their risk, are detailed as follows.

- The RBES Vision assumes that all MDAs will be covered in place. However, this remedy may not be possible for MDA B based on additional characterization information. MDA B contains containerized liquids and cover stability may not be achievable. Should a different remedial alternative be determined to be appropriate for MDA B, a variance from the RBES assumption would result.
- New Mexico Environment Department (NMED) may not agree with the end state as described. The Consent Order currently allows for industrial scenarios, however all sites that have been completed and approved to date have been cleaned to residential levels. A change in NMED’s position on allowing industrial level cleanups would lead to a variance.
- The D&D program plans for the removal of processed-contaminated facilities; many of which sit on top of and limiting access to legacy subsurface contamination whose cleanup is contained in the baseline. If the D&D program continues to remain unfunded, EM can not complete cleanup of the subsurface, and a variance will result.
- The RBES Vision assumes that LANL can control groundwater exposure at the supply wells and at the Laboratory boundary, and that no treatment of groundwater will be necessary. If NMED requires any regional groundwater to

meet groundwater standards, LANL may have to remediate groundwater, leading to a variance.

- The RBES Vision assumes that no remediation of alluvial waters will be necessary. No exposure route exists to alluvial waters on Laboratory property. However, should NMED define alluvial waters as groundwater and require the application of groundwater drinking standards to them, a large variance would result. In addition, San Ildefonso Pueblo (adjacent to the Laboratory boundary) potentially could place a shallow well in alluvial waters on Pueblo property and LANL would have no control over exposure at that point.
- The RBES Vision assumes that no remediation will be necessary for perchlorate in groundwater. However, perchlorate has been found in isolated alluvial and regional groundwater locations. A variance would result if NMED were to require cleanup for perchlorate in groundwater.

LANL has identified these risks in the current baseline, has developed a mitigation plan, and is managing them to minimize the potential of their occurrence.