# Verifying Environmental Performance through Inventory and Assessment: Case Study of the Los Alamos National Laboratory Waste Compliance and Tracking System

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***Abstract*—To address an important set of unverified field conditions, the Los Alamos National Laboratory Waste Compliance and Tracking System (WCATS) Wall-to-Wall Team performed an unprecedented and advanced inventory. This reconciliation involved confirmation analysis for approximately 5850 hazardous, low-level, mixed low-level, and transuranic waste containers located in more than 200 staging and storage areas across 33 Technical Areas. The interdisciplinary team scoped, planned, and developed the multidimensional assessments. Through coordination with cross-functional site hosts, they were able to verify and validate data while resolving discrepancies identified in WCATS. The results were extraordinary with an updated inventory, tailored outreach, more cohesive communications, and timely closed-loop feedbacks.

***Keywords*—Circular economy, environmental performance data, social-ecological-technological systems, waste management.

## I. Introduction

ALONG with the recent international attention surrounding the 26th United Nations Climate Change Conference of the Parties (COP26) in Glasgow, Scotland, the majority of Americans (64%) recognize the salience of environmental protection as an urgent and top priority [1]. From the global to the local, in this time of the Anthropocene, communities are galvanizing. For example, many local governments such as Los Alamos County, New Mexico have formed Resiliency, Energy, and Sustainability-related community-led initiatives to take action on these issues with new urgency [2]. This is also the case at Los Alamos National Laboratory (LANL or Laboratory); a unique and complex institution with a storied history (see Fig. 1 for LANL Technical Areas and surrounding lands). Building on that heritage as part of what US Secretary of Energy Granholm has described as America's "solutions department" [3], the current strategic LANL agenda is focused on: nuclear security; mission focused scientific, technical, and engineering; mission operations; and community relations [4]. Environmental, safety, and health (ESH) connections are essential to all of the noted agenda objectives. And accurate, reliable, and timely data are needed to effectively evaluate environmental performance goals [5]. As part of managing the dynamic ESH activities at LANL, the state-of-the art WCATS was implemented in 2010 to successfully integrate waste management activities across functional areas (see Table I for the variety of LANL waste types, methods of disposal, and amounts). In particular, WCATS is a software application that incorporated the migration of electronic data from multiple pre-existing databases [6]. It has been specifically designed to manage LANL's wastes from cradle-to-grave. The interactive tool provides the proper support needed for the waste cycle: planning, forecasting, generation, characterization, processing, storage, treatment, shipment, and final disposal of wastes [7].

LANL has a tripartite governing policy for the environment which includes commitments to stewardship; continuous improvement; and risk-reduction/sustainability [8]. Management of wastes generated by Laboratory operations is a crucial component of compliance with environmental laws. Key federal and state rules such as DOE Order 435.1, Radioactive Waste Management; Resources Conservation and Recovery Act; 2016 Compliance Order on Consent; Federal Facility Compliance Act; and New Mexico Hazardous Waste Act provide regulatory drivers. Along with meeting federal, state, and local regulations, Laboratory-specific ESH policies, directives, and procedures are designed to guide a diverse array of highly decentralized activities within a multilayered requirements structure and hierarchy [9]. Specifically, primary institutional requirements for environmental and waste management processes include but are not limited to: SD400-Environmental Management System, P409-LANL Waste Management, and the Hazardous Waste Facility Permit [10]-[12].

Due to its clandestine origin story as a "Secret City" of the Manhattan Project requiring the highest levels of security including its isolated location, LANL research facilities have developed somewhat independently. The corollary is a web of waste management processes which historically have been relatively disparate and semi-autonomous [13]. As early as 1948, the Atomic Energy Commission recognized the

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importance of institutionalized waste management [14]. Fast forward seven plus decades and in addition to the core LANL Environment and Waste Programs (EWP) functions, a distributed cadre of deployed ESH professionals, waste management coordinators (WMCs), and packaging specialists provide facility-level rooted support for generators at each of the Technical Areas on a day-to-day basis. However, with the velocity and flux of ever evolving R&D projects, construction, operations, demolition, and legacy cleanup initiatives, a distinct lag-time puzzle of uncertainty emerged. Verifying feedbacks across the laboratory campus requires broad collaboration and on the ground mobilization vis-à-vis WCATS auditing. Therefore, a central question crystallized: How can the robust assortment of waste streams within WCATS and varied waste practices across the vast network of Laboratory facilities be effectively inventoried, measured, and validated?

## II. Description

By internalizing ESH values, principles, and tools into organizational systems and culture, better outcomes can be achieved [15]. Per LANL System Description, SD400, Environmental Management System, the first important step for formal LANL approval of potential waste management begins with the Integrated Review Tool (IRT), a decision hub that interfaces with the Permits and Requirements Identification (PRID) Tool [10]. Subject Matter Experts (SMEs) from key disciplines and programs through use of the PRID Tool conduct extensive reviews of all proposed actions submitted by proponents to determine which multimedia approvals and permits may be required. For example, if a hazardous waste permit is required, the generator, WMC, SMEs, leaders, and intergovernmental partners can work together through formal coordination (e.g., Integrated Project Team [IPT]) and use of policies and procedures, such as P409 LANL waste management, which incorporate decision hierarchies [16] to ensure that the IPT has thoroughly scoped all lifecycle stages; and have planned for the safe, efficient, sustainable, and just path forward. Concurrently and symbiotically, efforts are initiated through WCATS to setup the necessary architecture configurations for waste requirements (see Fig. 2 for WCATS main screen format). This opens up options for creatively analyzing waste streams as potential feedstock for materials, energy, and information flows; through industrial ecology and circular economy inspired frameworks [17]-[19]. Accordingly, it is recognized that pollution prevention and waste minimization are preferred; and ultimately Waste Remediation (WR) can be an important ecosystem service for protection of human health and the environment [20]. Therefore, a conceptual framework for understanding and advancing lessons from this interdependent Social-Ecological-Technological system (SET) case study can be used [21], [22]. Consequently, the (S) are the human dimensions involving the LANL workforce and broader communities; the (E) are the natural settings including northern New Mexico and associated ecosystems involved; and the (T) are the infrastructure and products as represented by WCATS.

TABLE I
LANL Waste Types and Disposal Methods [8]

| Waste Type | Method for Disposal | Disposal Amount (2019) |
|---|---|---|
| Solid Transuranic Waste and Solid Mixed Transuranic Waste | The Laboratory sends solid transuranic and mixed transuranic wastes offsite to the Waste Isolation Pilot Plant in Carlsbad, NM, when the transuranic or mixed transuranic waste meets the plant's waste acceptance criteria. Some transuranic and mixed transuranic waste is stored at the Laboratory while waiting for an acceptable disposal pathway to be identified. In 2019, LANL waste was also shipped from long-term storage at Waste Control Specialists (Andrews County, TX) to WIPP. | 8,270 cubic yards (6,322.5 cubic meters) from LANL; 4 cubic yards (3.1 cubic meters) from Waste Control Specialists in Andrews County, Texas |
| Solid Low-level Radioactive Waste | The Laboratory sends solid low-level radioactive waste offsite to licensed treatment, storage, and disposal facilities. These sites include the Nevada Nuclear Security Site, operated by the DOE, and commercial facilities operated by Energy Solutions (Clive, UT); Perma-Fix Northwest, Inc. (Richland, WA), and Waste Control Specialists (Andrews County, TX). | 48,957 cubic yards (37,431 cubic meters) |
| Liquid Radioactive Waste | The Laboratory treats liquid radioactive waste onsite at the Radioactive Liquid Waste Treatment Facility in TA-50. The treated water is either evaporated or released at permitted Outfall 051. | 694,982 gallons |
| Solid Hazardous Waste | The Laboratory sends solid hazardous waste offsite for treatment and disposal at licensed treatment, storage, and disposal facilities. In 2019, these facilities included Veolia North America (Henderson, CO) and Clean Harbors (Clive, UT). | 150 tons |
| Solid Mixed Low-Level Waste | The Laboratory sends solid mixed low-level waste offsite to licensed TSDFs. In 2019, these facilities included Energy Solutions (Clive, UT), Perma-Fix of FL, Inc. (Gainesville, FL), and Waste Control Specialists (Andrews County, TX). Some mixed low-level waste is treated at one of the licensed treatment, storage, and disposal facilities to meet land-disposal restrictions and is then disposed of at the Nevada Nuclear Security Site. | 6,108 cubic yards (4,670 cubic meters) |
| Solid Nonhazardous Waste | The Laboratory sends sanitary solid waste, construction debris, and demolition debris to the Los Alamos County Eco Station for transfer to municipal landfills such as the landfill in Rio Rancho, NM. LA County operates this transfer station and is responsible to the State of NM for obtaining all related permits for these activities. The Laboratory also sends solid nonhazardous waste to regional facilities in AZ and CO. | 2,727 tons |
| Liquid Sanitary Waste | The Laboratory treats liquid sanitary waste onsite at the Sanitary WWTP. Treated water is reused in Laboratory cooling towers and is released at permitted Outfall 001. | 1,249,214 gallons |
| PCB Wastes | Waste containing PCBs, including fluorescent light ballasts and contaminated soils, was sent to U.S. EPA-authorized TSDFs, including Clean Harbors (Clive, UT) and Veolia North America (Henderson, CO). | 358 tons |
| Asbestos Waste | Asbestos-containing waste is deposited at any of several waste disposal sites operated in accordance w/ 40 CFR 61, 154 | 88 tons |

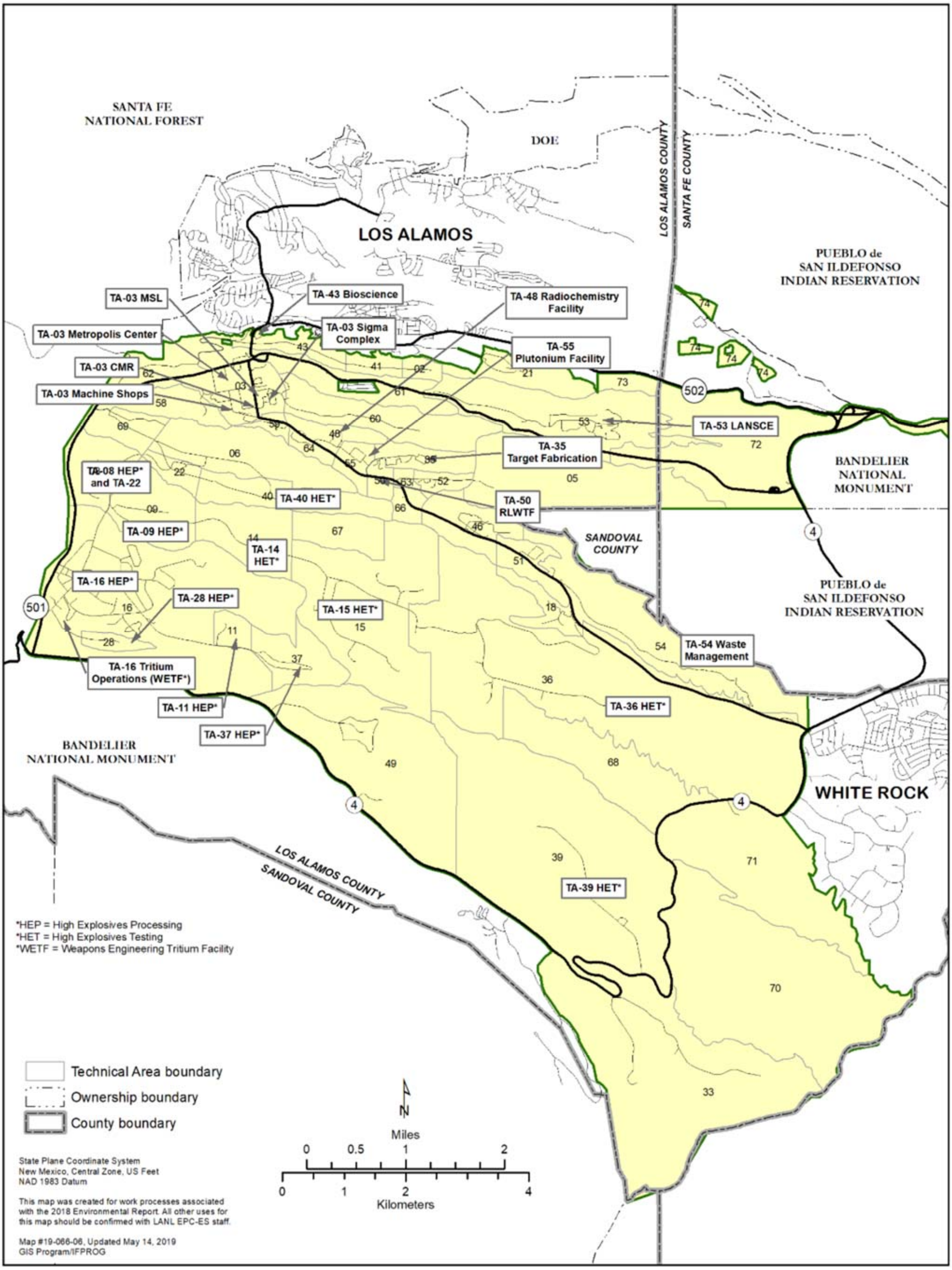


Fig. 1 LANL Technical Areas and surrounding lands [8]

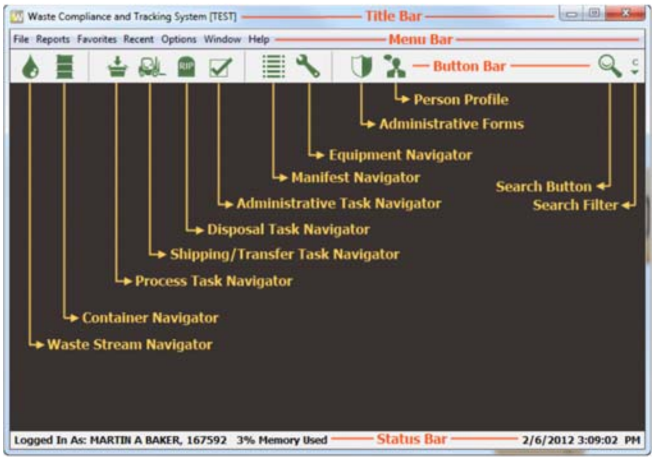


Fig. 2 WCATS main screen [7]

To advance the effort of establishing the capacity of WCATS to sustain WR in the face of acute and chronic stresses with ongoing evolution and improvement, a tiered process took place. First, the properties of WCATS were thoroughly analyzed. Second, implications for the key attributes of the broader LANL institutional governance arrangements continue to be put forward.

The first phase of the LANL Wall-to-Wall Inventory (W2W) Team was comprised of multidisciplinary members with distinct academic and professional backgrounds including: various ESH programs, areas of regulatory specialty, waste expertise, software engineering, database experience, technology training and transfer, and metric development skills; all of which contributed to the success of the project. They met daily to communicate the plan of the day, assign and provide status on actions, determine facility schedule, ensure access was granted, and discuss outstanding issues or concerns before reporting to sites. Some had the ability to query WCATS to generate ad-hoc reports to track process and define the scope of the project, others provided WCATS training for users and other members of the team, some had backgrounds in quality assurance/quality control (QA/QC), data presentation, graph and metric data, and document preparation. The team collaborated with each other, partner organizations and facility subject matter experts that managed the staging/storage areas to be able to accomplish the inventory with efficiency and accuracy while minimizing impacts to routine operations.

The W2W Team leveraged existing protocols and data while preparing and developing a pragmatic proposal for performing this unprecedented strategic initiative by conducting research, analysis, and project scoping [23]. Empowered with authorization by LANL leadership as illustrated by laboratory-wide notifications, their creative and innovative approach in establishing the methods of the project, querying the WCATS baseline inventory report for designated areas to identify the number of sealed/closed containers and items in the database, and building the platform to evaluate approximately 5850 waste containers and items on site proved to be effective. Following pilot scale tests, they geospatially verified the location and status of over 3000 containers and items (~52%) in onsite staging/storage areas in nearly 200 locations across 33 Technical Areas; while also closing the data loop on those dispositioned off site. For instance, given the numerous types of waste streams generated at LANL, many commercial off-site Treatment, Storage, Disposal Facilities (TSDFs) are partners for ultimate disposal in the WR interstate network (e.g., UT, NV, TN, WA, CO, NM, and TX). The evaluation process included review of available container data such as histories, shipping manifests, supporting reports, field logs, and employee interviews to identify and ground truth any relics. Clarification of these records provides a more accurate representation of active waste storage by LANL [6].

## III. Discussion

The field component of the initiative took place from June 2019 through January 2020. As part of the SET, the cross-functional W2W Team developed new procedures, checklists, and processes used to: execute the work in the field, decommission items in WCATS, manage, track and develop reporting metrics and graphs. The team used held-hand mobile devices to scan and record 3600 containers on-site and evaluated how wide spread the use of these mobile devices was by embedded facility personnel [24]; see Fig. 3 for examples of mobile device and waste containers in storage. The W2W team developed a two-person (buddy strategy) approach to independently scan containers and then compare results to ensure that no containers were missed or double counted. The procedures and checklists were revised based on experience to improve the efficiency and accuracy of the inventory as they conducted the verification.

The multidimensional assessment process was flexible enough to accommodate special situations. An example was inventorying waste containers at TA-55, where arduous security, potential radiation exposure, and the significant number of waste containers made the traditional approach impractical. Instead, the WCATS inventory was compared to Nuclear Material Control and Accountability (NMCA) information contained in the Local Area Nuclear Material Accountability Software (LANMAS) database for transuranic wastes. Due to rigorous DOE and LANL standards, the quality of the LANMAS data is very high and was deemed adequate to authenticate the data in WCATS. This allowed the inventory of those items to be cross-walked and completed with minimal safety and security risk and no violations.

Overall, the W2W Team synchronized with all levels of management, waste generators, deployed ESH professionals, WMCs, packaging/transportation services leaders, and facility representatives to organize access approvals, obtain escorts as required, ensure site access training, walk-down the facility sites, report issues and concerns, develop and convey WCATS training and changes, and to provide monitoring. Diligent, rigorous, and iterative steps were taken to account for containers throughout the waste management continuum and their operational and administrative status. From being under the control of generators to being processed, packaged, and transported on-site or shipped off-site during the noted interval a more accurate empirical distribution was ascertained. In summary, more than half of the baseline containers and items were physically confirmed. Containers present in the WCATS database but not located on-site were potential database migration relics (e.g., containers or items that were a product of the transfer of historic database records into the WCATS database).

Due to the information migration, container histories were sometimes incomplete, re-packaging, and shipping histories on paper-based systems were not effectively captured electronically. Of this artifact portion, reconciliation efforts directly reduced the active waste container inventory by decommissioning and other clarifying mechanisms. The synergistic initiative resulted in improved data quality, streamlined processes, better management operations, and capacity building. Lessons learned from this visionary strategy can be evaluated for customization and potential replication at other DOE laboratories, production facilities, and beyond.

The SET is consistent with the cradle-to-cradle guidance by McDonough and Braungart [25] for design innovators and organizational leaders, as the W2W initiative continues to: signal intention (LANL distinguished performance award for the effort); restore (building capacity); innovate further (re-engineering and upgrade of WCATS and next generation mobile devices); understand and prepare for the learning curve (new procedures and outreach); and exert intergenerational responsibility (succession planning through mentoring, cross-training, and partnerships).

Fig. 3 WCATS Mobile Device and Waste Containers [7]

## IV. Conclusions

Several macro-level institutional compliance feedback mechanisms were strengthened and reinforced such as: the Issues Management actions to provide revisions and updates to the Laboratory's Waste Management Policy, P409; crosswalks with the Hazardous Waste Facility Permit; linkages with the Environmental Management System; and many internal procedures in multiple organizational units to ensure principles for building resilience and sustaining ecosystem services. The second phase of the W2W Team continues to exhibit the unusual commitment and dedication by ensuring that WCATS remains accurate and current as new containers and items are added to the software. This effort is being accomplished by hiring new data stewards to track and monitor data, ongoing mentoring and training for users of the network, developing over 45 training videos during the pandemic, and ensuring system updates are completed in a timely manner. The original estimate was that the Wall-to-Wall inventory would take approximately one year to complete. The team continued to demonstrate going above and beyond normal expectations by refining the process and coordinating efforts with host facility site personnel, resulting in the inaugural field work portion of the inventory being completed in approximately five months. The W2W Team demonstrated schedule flexibility to prevent impact to facility operations and avoided curtailing or pausing site activities.

With respect to next steps for the project, it is recommended that the resilience of WR, a key ecosystem service as managed by WCATS, continue to be evaluated. This represents an impactful area of ESH knowledge and practice for supporting current and future LANL needs. By using the principles of SET: 1) diversity and redundancy; 2) connectivity; 3) slow variables and feedbacks; 4) complex systems thinking; 5) learning; 6) participation; and 7) polycentricity; advances can be developed toward best practices, gap analysis, and the path forward to sustainable, regenerative, and long-term stewardship.

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