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A Review of Policies and Regulations Governing Mine Tailings and Waste in the U.S

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Abstract

Meeting U.S. critical mineral needs for the clean energy transition while ensuring environmental protection requires an updated regulatory framework for mine tailings and waste. This review examines the evolution of U.S. mining law from the General Mining Law of 1872 through successive environmental statutes (NEPA, Clean Water Act, RCRA, CERCLA), illustrating how this layered legal framework shapes modern mine waste management. Federal permitting processes for mining projects are analyzed, with attention to interagency coordination, bonding requirements, often lengthy NEPA review timelines, and recent reforms to streamline approvals (e.g., FAST-41 and new 2025 federal initiatives). The study evaluates reclamation bonding and tailings management standards, highlighting the prominent role of state regulations and the absence of a unified federal tailings dam safety law. New policy measures, including the Good Samaritan Remediation of Abandoned Hardrock Mines Act of 2024 and Interior Secretary's Order 3436, are reviewed for their potential to facilitate mine waste remediation and critical mineral recovery. Case studies from Arizona, Nevada, Utah, Alaska, and California illustrate diverse state-level mining and waste permitting regimes, complemented by comparative tables contrasting state and federal standards. Key policy gaps and reform opportunities are identified, such as instituting a federal hardrock mining royalty, further streamlining permitting processes, addressing ESG pressures, reducing liability barriers to tailings reprocessing, and advancing circular economy goals. The analysis underscores the importance of aligning mine waste regulation with critical mineral supply needs and environmental protection, and calls for interdisciplinary solutions spanning policy, law, engineering, and sustainability.

Introduction

Mining of hardrock minerals in the United States is governed by a complex framework of federal and state policies that has evolved over more than a century. Early mining laws prioritized resource extraction with few environmental safeguards, most notably the General Mining Law of 1872, which opened public lands to mineral exploration and allowed miners to claim minerals without paying federal royalties [1]. In the late 20th century, growing awareness of environmental and social impacts led to new layers of regulation at the federal and state levels. Today, the permitting of mines and even the reprocessing of mine tailings (the finely ground waste from mineral processing), waste rock, and spent ore (heap leach residues) requires navigating multiple agencies and compliance with environmental laws. This review provides a comprehensive overview of current U.S. policies governing mining and reclamation of mine waste, with emphasis on federal laws and on case studies from major mining states (Arizona, Nevada, Utah, Alaska, California, among others). Historical context is integrated to explain how today's regulatory frameworks emerged, and we highlight key aspects including permitting procedures, environmental compliance standards, critical mineral recovery initiatives, public engagement mechanisms, and interagency coordination. We compare how different states build upon or diverge from federal requirements, particularly in the context of reprocessing mine wastes for critical minerals or environmental remediation. Finally, we discuss policy challenges and opportunities for fostering innovation and sustainability in mine waste management, aligning mining practices with circular economy and energy transition goals.

Federal Regulatory Framework

Evolution of Federal Mining Law and Environmental Statutes

The foundation of U.S. mining policy on federal lands remains the General Mining Law of 1872 (30 U.S.C. §§21–54), an antiquated statute that still governs "locatable" hardrock minerals such as gold, copper, lithium, and others on public domain lands [2]. The 1872 law codified mining camps' practices from the gold rush era and declared all valuable mineral deposits on U.S. federal lands to be "free and open" for exploration and purchase by citizens [1,3]. Under this

law, a prospector may locate a mining claim, gain rights to extract minerals, and (historically) even patent the land into private ownership (though Congress imposed a moratorium on new patents in 1994; ICLG, 2026) [2]. Notably, unlike oil, gas, or coal extraction under later laws, hardrock mining under the 1872 law incurs no federal royalty, meaning companies pay no royalties to taxpayers for minerals taken from federal land [1]. This lack of royalty and the law's minimal provisions for environmental protection have prompted calls for reform for decades, yet the core of the 1872 Mining Law remains in place.

In the absence of early environmental controls in mining law, the mid-20th century saw a patchwork of federal environmental statutes applied to mining operations. Key laws include the National Environmental Policy Act (NEPA) of 1969, which requires environmental impact assessments for major federal actions; the Clean Water Act (CWA) of 1972, which regulates discharges of pollutants to waters (including mine process effluent and tailings pond discharges); the Clean Air Act of 1970, which limits air emissions (e.g. dust and smelter fumes) from mining and processing; and the Endangered Species Act of 1973, which can restrict mining activities that harm protected species or habitats [2]. In 1976, the Federal Land Policy and Management Act (FLPMA) was enacted, governing land use on Bureau of Land Management (BLM) lands, FLPMA directs that public lands be managed to prevent "unnecessary or undue degradation," which has been interpreted to require reclamation of mined lands and protection of environmental values [2]. FLPMA and related regulations (43 C.F.R. §3809 for BLM lands) mandate that mining operators submit and get approval of a Plan of Operations including a detailed reclamation plan and financial assurance (bond) before disturbance on federal lands [2]. The U.S. Forest Service (USFS) has parallel regulations (36 C.F.R. Part 228 Subpart A) for mining in National Forests, requiring that operations minimize adverse impacts and similarly requiring reclamation measures and bonding [2].

Another pivotal law is the Resource Conservation and Recovery Act (RCRA) of 1976, which regulates hazardous waste. Notably, in 1980 Congress amended RCRA with the "Bevill Amendment" to temporarily exempt "extraction and beneficiation" mine wastes, including tailings and waste rock, from the strict hazardous waste rules, pending further study. To this day, mine tailings and related wastes are not regulated as hazardous waste under RCRA Subtitle C, even if they contain toxic heavy metals or chemicals, as long as they are managed on site [3]. Instead, mine wastes are governed under mine-specific regulations and state programs. Similarly, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund, 1980) can apply to mining sites by imposing liability for releases of hazardous substances; many abandoned mine sites with acid drainage or tailings contamination have become Superfund cleanup sites. However, CERCLA's strict liability regime also had a chilling effect on voluntary cleanup or reprocessing of old mine waste, as anyone disturbing a contaminated site could become liable for the entire cleanup. We will discuss recent policy changes addressing this barrier (the 2024 "Good Samaritan" law) later in this review.

Parallel to these environmental laws, federal legislation for specific minerals has been layered onto the 1872 framework. The Mineral Leasing Act of 1920 moved fuel minerals (coal, oil, gas, oil shale, etc.) to a leasing system with royalties, and the Surface Mining Control and Reclamation Act (SMCRA) of 1977 established strict permitting, performance standards, and reclamation fund requirements for coal mining. Hardrock minerals, however, were not covered by SMCRA's national reclamation program. Thus, hardrock mine regulation has relied on a combination of the 1872 Mining Law (access and rights), FLPMA (land management and reclamation on federal land), and the general environmental laws noted above. In practice, this means hardrock mining on federal lands entails compliance with multiple concurrent federal and state regulations [2]. For instance, a large gold mine on federal land must not only adhere to BLM/USFS mining regulations and submit a reclamation bond, but also obtain CWA permits for any water discharges (often through state agencies via delegated authority) and meet air quality standards, all while undergoing NEPA review and consulting on impacts to species or cultural resources.

Federal Permitting Process and Interagency Coordination

Permitting a mining project on federal land is a multi-stage process. First, rights to the mineral must be established, for locatable minerals, this means staking mining claims and meeting requirements under the 1872 Law and FLPMA (e.g. paying annual claim maintenance fees; ICLG, 2026) [2]. Exploration activities beyond casual prospecting usually require notification or approval: on BLM lands, exploration above certain disturbance thresholds triggers a Notice or Plan of Operations under 43 C.F.R. 3809, and on USFS lands, a Notice of Intent or approved Plan is required (36 C.F.R. 228.4). Once a company proposes a full mine development, a detailed Plan of Operations must be submitted to the land management agency (BLM or USFS), including mine plans, tailings storage plans, a reclamation and closure plan, and evidence of financial assurance sufficient to cover reclamation costs [2]. The agency is required to review the plan for compliance with regulations (ensuring no undue degradation and minimization of impacts) and to initiate NEPA review if the action is a major federal action.

Under NEPA, federal agencies must evaluate the environmental impacts of the project, considering alternatives and mitigation. Typically, a large mine will require an Environmental Impact Statement (EIS) due to its significant effects, although in some cases a shorter Environmental Assessment may suffice if impacts are not significant [2]. The NEPA process necessitates interagency coordination and public engagement: the lead agency (e.g. BLM) consults with other federal and state agencies with jurisdiction or expertise (for example, the U.S. Army Corps of Engineers if wetlands or navigable waters are affected, the U.S. Fish and Wildlife Service if endangered species or habitat may be impacted,

state environmental agencies for water and air permits, and tribal governments if ancestral lands or cultural sites are involved). NEPA also requires public notice of the proposed project and opportunities for the public to comment on draft EIS documents and during scoping. Public hearings are commonly held in affected communities. These mechanisms allow local communities, Indigenous tribes, and other stakeholders to voice concerns or support, and agencies must respond to substantive comments in the final EIS [2]. NEPA does not mandate a particular outcome, but it ensures a thorough consideration of environmental and social impacts (including water, air, wildlife, cultural resources, etc.) in decision-making [2].

In recent years there have been efforts to streamline federal permitting for mines, especially those supplying "critical minerals" deemed essential for national security and clean energy. The FAST Act of 2015 created a Federal Permitting Improvement Steering Council and the FAST-41 process to coordinate and expedite reviews for large infrastructure projects. In 2023, the Permitting Council moved to include more mining projects (particularly critical mineral supply chain projects) under FAST-41, aiming to reduce duplicative reviews and set timeline goals [2]. Additionally, the NEPA regulations themselves have been in flux: in 2020 the Trump Administration revised NEPA rules to limit the scope of reviews (e.g. no longer requiring cumulative impacts analysis) and set strict time limits, and in 2023-2025 the Biden Administration and Congress further addressed permitting timelines. By mid-2025, individual agencies like the Army Corps, DOE, DOI, etc. issued their own NEPA implementing procedures emphasizing efficiency and time limits [2]. One notable change was allowing agencies to set page and time limits and not be "micromanaged" by courts in their NEPA analysis, per a May 2025 Supreme Court decision [2]. Furthermore, an "OBBBA" (presumably the Omnibus Budget bill) authorized project sponsors to pay extra fees for accelerated NEPA review, a fast-track option where paying 125 % of review costs requires agencies to complete an Environmental Assessment within 180 days or an EIS within one year [2]. These changes are expected to speed up federal mine permitting, though they have been controversial in potentially reducing environmental scrutiny [1].

Throughout the permitting, interagency coordination is critical. Often a single EIS can be used to satisfy federal and state environmental review requirements via cooperation agreements [2]. For example, a state may be a cooperating agency on the federal NEPA review and simultaneously use that review to inform its own permits. In some states (e.g. Alaska), there are formal coordinated permitting processes: Alaska employs a "Permit to Mine in Alaska" (APMA) unified application, which is circulated to all relevant state and federal agencies, streamlining the permitting process for the applicant. This kind of coordination helps avoid conflicting requirements and can allow one environmental analysis to serve multiple permits. Still, agencies have distinct roles: the EPA (or state DEQ) will issue a CWA Section 402 permit for any discharge to waters (requiring the mine to meet effluent limitations for mine water or tailings effluent, the Army Corps of Engineers handles Section 404 permits for any placement of mine waste or fill material into wetlands or waterways (such as tailings dam construction in waters of the U.S.), and state agencies typically handle water rights or groundwater protection permits [4]. The Bureau of Land Management or Forest Service focuses on land and resource management aspects (surface impacts, reclamation, adherence to mining law). Thus, a mining proponent must obtain a suite of permits and approvals before construction: a Plan of Operations approval (with NEPA completed), water discharge permits, air quality permits for dust or emissions, often a stormwater permit, and others like hazardous materials management plans, cultural resource mitigation plans, etc. Only after all these are in place (and often after years of analysis and public scrutiny) can construction and operations commence.

Environmental Compliance: Tailings Management and Reclamation Standards

A major focus in modern regulation is preventing environmental contamination from mine wastes, particularly tailings impoundments, waste rock dumps, and leach pads, and ensuring proper closure. Federal land managers require that mine plans include comprehensive plans for waste management and eventual closure. Under BLM regulations, for example, any proposed tailings storage facility on public land must be designed to avoid "unnecessary or undue degradation," and the Plan of Operations must describe how tailings and other waste will be stabilized and reclaimed [2]. BLM's rules (43 C.F.R. §3809.420) set performance standards such as saving topsoil for post-mining reclamation, controlling erosion and water infiltration, isolating or treating any toxic materials in the tailings, regrading and revegetating disturbed areas, and rehabilitating habitat where practicable [2]. Similarly, the USFS regulations (36 C.F.R. §228.8) require operators to prevent or control runoff, acid drainage, and seepage from tailings or waste rock, and to remove or neutralize any toxic materials to avoid water contamination [2]. In practice, both agencies defer to engineering best practices and often to state dam safety regulations for the detailed design of tailings dams [3]. It is notable that there is no single federal mine tailings dam safety law, oversight of tailings dam design, construction, and monitoring is primarily the domain of state agencies or a patchwork of federal guidelines. For example, after several international tailings dam failures (e.g. Canada's Mount Polley 2014), U.S. regulators encouraged adoption of updated industry standards (the Global Industry Standard on Tailings Management, 2020), but implementing such standards is largely voluntary or at the state level [3]. The Department of the Interior's 2022 interagency working group report noted that federal guidance on tailings dam closure is limited and that more state-level reform may be needed to align U.S. practices with modern safety standards [3].

Reclamation bonding is a crucial component of environmental compliance. Both federal and state laws require that mining operators post a financial guarantee (bond, letter of credit, trust fund, etc.) before commencing operations, in an amount sufficient to cover the full cost of mine closure and reclamation in case the operator fails to do so [2].

This includes earthwork to regrade tailings piles or waste dumps, water treatment needs, re-vegetation, and long-term monitoring. On federal lands, BLM and USFS will not approve a Plan of Operations until the reclamation bond is secured; likewise, states typically will not issue their permits without a bond. The bond amounts are reviewed periodically and can be adjusted if conditions change (for instance, if additional waste is produced or if new water treatment needs arise; Arizona mining permitting guide, 2017) [5]. Coordination occurs to avoid "double bonding", typically a single reclamation bond can be co-held or shared by federal and state agencies through agreements, so the operator is not posting two separate full-cost bonds; Arizona mining permitting guide, 2017 [5].

Despite these measures, long-term environmental issues remain a challenge. Many modern mines involve perpetual water treatment, for example, mines that generate acid mine drainage may need water capture and treatment for decades or centuries after closure to protect streams. Neither federal law nor most states originally contemplated such long timeframes. Some states have begun to require long-term trust funds or other financial mechanisms to address perpetual treatment. For instance, Montana and Alaska have policies that if a closed tailings facility or waste rock pile will require water treatment or maintenance indefinitely, the company must provide a financial assurance mechanism (like a trust) to fund that future work [6]. Federal land managers also incorporate long-term post-closure water management plans in their approvals, but ensuring funding beyond the life of a company is an evolving area of policy. As of now, federal regulations do not explicitly mandate funding for perpetual water treatment, so agencies rely on case-by-case bond calculations or environmental mitigation agreements to cover reasonably foreseeable post-closure costs.

Another aspect of federal oversight is liability for contamination. Under CERCLA, if a spill or release from a tailings facility occurs (for example, a dam failure or leakage of toxic metals to groundwater), the mining company can be held liable for cleanup costs and natural resource damages. The Superfund program has addressed numerous historic mine sites (e.g. lead-zinc mines in Idaho's Silver Valley, or gold mine tailings in Colorado's Leadville area). Knowing this, modern operators strive to design facilities to prevent releases and also to formally close and reclaim sites so that they are not "abandoned" and subject to Superfund listing. A lingering policy gap had been how to encourage remediation or reprocessing of legacy mine wastes that were left by defunct operators. Because touching a contaminated site could trigger CERCLA liability or Clean Water Act permit requirements, even well-intentioned parties (such as local governments or conservation groups) have been reluctant to clean up old tailings piles or acid drainage. This has begun to change with the passage of the Good Samaritan Remediation of Abandoned Hardrock Mines Act of 2024. Signed into law in December 2024, this act created a pilot Good Samaritan program under which "Good Samaritan" entities can apply for a permit to remediate an abandoned mine site, including activities like waste rock removal or tailings stabilization, without incurring the usual CERCLA or Clean Water Act liability, so long as they comply with the permit's conditions [7]. The law allows up to 15 such Good Samaritan remediation permits initially, providing a legal pathway for third parties to clean up legacy mine waste sites (often while improving water quality) without being punished for undertaking those corrective actions [7]. This is an important recent policy development linking environmental remediation goals with regulatory relief.

Critical Minerals and Reprocessing of Mine Waste: New Federal Initiatives

In the context of the clean energy transition and supply chain security, U.S. policymakers have turned attention to extracting critical minerals (such as rare earth elements, lithium, cobalt, tellurium, etc.) from unconventional sources, including mine tailings, spent ore heaps, and waste rock. These materials can contain residual metals of value, and recovering them can both provide new supply and help remediate environmental hazards. However, current laws did not clearly address whether reprocessing old mine waste constitutes "mining" (thus requiring a full mine permit) or "remediation," and how such projects might navigate rules originally written for primary mining. In July 2025, the Department of the Interior (DOI) took a significant step by issuing Secretary's Order 3436, "Unlocking Critical and Strategic Minerals from Mine Waste, Cutting Red Tape, and Restoring American Dominance in Strategic Mineral Production." This order directs DOI bureaus to rethink and reform regulations to facilitate recovery of critical minerals from mine wastes [8]. Several key measures are outlined in the order:

Clarifying Regulatory Scope

The order seeks to ensure that tailings reprocessing projects are not inadvertently stymied by regulations meant for primary mining. For example, it addresses the ambiguity in SMCRA (the coal mining law) about whether extracting minerals from coal waste piles counts as "surface coal mining" requiring a coal mine permit. The DOI is instructed to promulgate rules confirming that reprocessing coal waste for critical minerals is not the same as mining coal, thus removing a potential regulatory hurdle [8]. This suggests that reprocessing coal refuse piles for rare earth elements or other critical minerals will not trigger all of SMCRA's requirements for a new coal mine, streamlining such projects.

Leveraging Federal Reclamation Funds

Large funds exist for reclaiming abandoned mine lands (AML), especially coal sites (funded by SMCRA fees) and non-coal sites via the Infrastructure Investment and Jobs Act 2021. Traditionally, these funds could only be used for environmental reclamation, not for commercial mineral extraction. The 2025 order directs agencies to clarify that existing federal grant programs for mine land reclamation may be used in conjunction with critical mineral recovery efforts [8]. Within 60 days, bureau heads were told to advise current AML funding recipients how they could integrate mineral recovery into cleanup, and DOI must consider formal guidance or rule changes to that effect [8]. This could be transformative: for

instance, a state using federal AML funds to clean up old mine tailings might partner with a company to extract critical minerals from those tailings as part of the project, turning a waste into a resource while still accomplishing remediation.

Expedited Permitting for Uranium and Critical Minerals

The order places special emphasis on uranium (still considered a critical mineral for energy). It directs the BLM to prioritize approval of any plans to extract uranium and associated critical minerals from mine waste, effectively jumping those proposals to the front of the line [8]. It also invokes provisions to use emergency permitting authorities under NEPA, the National Historic Preservation Act, and the Endangered Species Act to speed up such projects [8]. Essentially, DOI signaled that if someone proposes to reprocess tailings containing uranium (e.g. from old uranium mines or mill tailings) and critical co-elements, the agencies should fast-track the environmental reviews using any available streamlining or categorical exclusions. While faster approval is beneficial to development, it raises questions about ensuring environmental and cultural protections, DOI acknowledged such fast-tracking carries "risks and rewards" and may invite litigation if seen as corner-cutting [8].

Future Rulemakings and Mapping

The order is forward-looking in calling for DOI to explore further regulatory changes that would encourage mine waste reprocessing. This includes examining whether fees such as the SMCRA Title IV abandoned mine land fee (a per-ton coal production fee) should apply or be waived for reprocessing coal waste piles (to avoid discouraging removal of waste; Annatoyn et al., 2025) [8]. It also raises the question of appropriate reclamation standards for projects that disturb old waste, presumably ensuring that after critical minerals are extracted, the remaining material is left in a more stable or environmentally benign state than before. DOI is also tasked with employing the U.S. Geological Survey to map and publicly share data on the location of mine waste resources on public lands, to help industry identify opportunities [8]. This reflects a shift in viewing historic mine waste piles as potential assets.

Overall, Secretary's Order 3436 represents a significant policy shift toward a circular economy approach in mining, encouraging the re-use of waste streams to recover valuable minerals, rather than only seeking virgin ore deposits. Its implementation will likely require regulatory changes to BLM and Office of Surface Mining rules in late 2025 and 2026. As of this writing, the durability of these reforms is uncertain; they could be subject to legal challenge or changes in priorities under future administrations [8]. Nevertheless, coupled with the Good Samaritan law (which removes liability barriers to cleanup-based reprocessing) and substantial federal funding for critical mineral research (e.g. DOE programs to extract rare earths from coal waste), the federal landscape is moving toward enabling innovative tailings reprocessing projects. An example is the Golden Sunlight Mine in Montana, where a recently approved project is reprocessing old tailings to extract remaining gold and sulfides, while simultaneously neutralizing the tailings to prevent acid generation. Such projects serve as prototypes for the dual goal of mineral recovery and remediation [9,10].

In summary, the federal framework governing mine waste is layered: the historical 1872 Mining Law grants access and priority to mining activities, but modern environmental statutes and land management rules impose requirements to prevent pollution, rehabilitate lands, and involve the public in decision-making. Where gaps remained, such as the treatment of abandoned waste sites and incentives to reprocess tailings, new policies in 2024-2025 have begun to fill them, signaling a more proactive stance towards sustainable mining and waste reuse at the national level.

State-Level Regulatory Case Studies

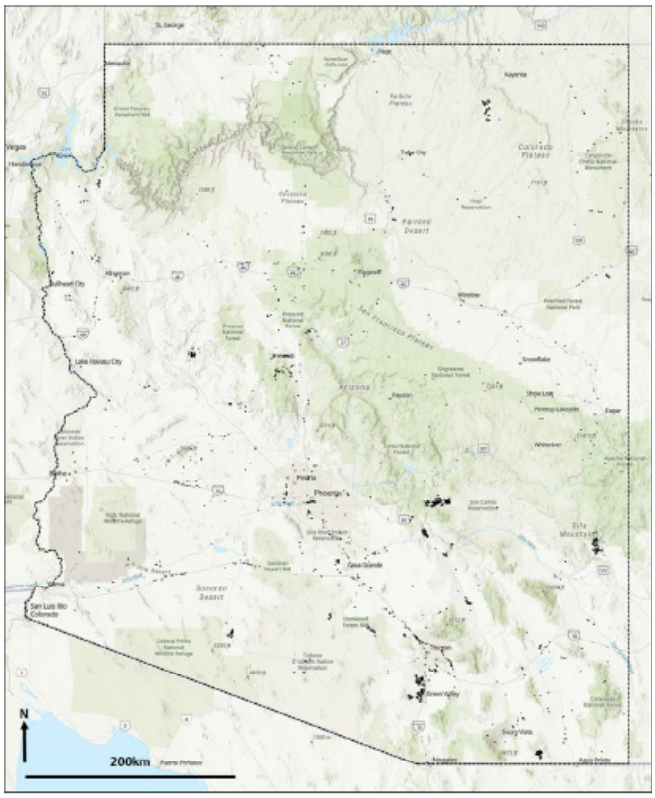
While federal law provides the baseline for mining on public lands, state governments play a pivotal role in regulating mining and reclamation, even on federal lands (through concurrent environmental standards) and especially on state or private lands. States with significant mining sectors have developed their own permitting processes, reclamation requirements, and in some cases, stricter standards than federal law. In this section, we review selected state frameworks, focusing on Arizona, Nevada, Utah, Alaska, and California, to illustrate how state-level policies augment and implement the regulation of tailings, mine waste, and related activities. Each of these states must reconcile mineral development with environmental protection and public interests, but their approaches reflect different legal histories and policy priorities. Table 1 (in the next section) will compare key regulatory features across these states. Here we describe each state's system and any notable innovations or challenges.

	Arizona	Nevada	Utah	Alaska
Low (locatable minerals on public ing Act for certain minerals); FLPMA nd management (BCLG, 2020).	• Arizona Revised Statutes Title 27 (e.g. 8827-881 et seq. for reclamation). • State Mine Inspector oversees mine safety & reclamation.	• Nevada Revised Statutes Chapter 519A (Reclamation of Land). • NRS Chapter 445A for water protection; mining-friendly policies with oversight by NDEP.	• Utah Code Title 40-8 (Mine Reclamation Act); DOGM rules R647 for mining; supportive of mining with regulatory oversight.	• Alaska Statutes Title 27.19 for reclamation • DNR as lead agency f cooperation/joint ar
required on federal land if above threshold (BLM 43 CFR 3809, USFS nificant.	• State exploration permits typically not separate, if >5 acres, treated as mine. • Smaller exploration may require Notice to State Land Dept. if on state land.	• Notice to NDEP for exploration <5 acres; >5 acres require reclamation permit (NDEP, 2020s). • BLM/USFS notice on federal land.	• Exploration <5 acres: file Notice with DOGM and bond. • >5 acres: full permit like mining operation.	• Exploration included small-scale use Letter • Large exploration req acres; CCB, 2020).
Plan of Operations required on land with NEPA EIS or EA; ICLG, ronment via NEPA; interagency er (ESA, MHPA).	• No state EIS law; uses federal NEPA if applicable. State requires Aquifer Protection Permit (APP), a quasi-EIS for groundwater. • Public comment on key permits.	• No state EIS; NEPA for federal lands common; NDEP permits include public notice (e.g. Water Pollution Control Permit). • State and BLM coordinate review.	• No state EIS statute; relies on NEPA for big federal projects. • DOGM permit reviews are public on request (Board hearings). • State agencies cooperate with NEPA.	• No state EIS law, but voluntary EIS via fede • Boro's APMA integ public notice for fish h
federal land (43 CFR 3809 for BLM), n & cost estimate, bond for 100 % of 2020). hardrock bond pool; company must	• Required for any mining on private/state land (>5 acres) via State Mine Inspector (Arizona mining permitting guide, 2017). • Bond required, amount case-specific; coordinates with federal bond if applicable.	• Required for >5 acres disturbance (state Reclamation Permit; NDEP, 2020). Bond required (calculated with standardized model). • NDEP, 2020s: BLM accepts state bond to avoid duplication.	• Required for all operations (small mines file reclamation notice + bond; large mines detailed plan). • Bond/surety required (often using corporate guarantees or cash). • DOGM holds bond until successful reclamation.	• Required for all mini CCB, 2020). • >5 acres: simple pl plan 45 days before s • Bond required, can small mines or port stormwater treatment
nt "undue degradation", agencies tailings disposal, liners if acid/toxic, ers (ICLG, 2020). ss exempt from RCRA hazwaste (U.S. of the Interior, 2022), but subject to t terms (US EPA 2020). quality standards. No specific fed law, rely on state dam safety (U.S. of the Interior, 2022) and MSHA	• Governed via APP (tailings impoundments must have liners/leachate control to protect aquifers). State dam safety applies (ADWR). • Some modern mines use dry-stack tailings to reduce water impacts. • Old tailings reprocessing subject to same permits as new mining.	• State Water Pollution Control Permits required for tailings facilities, mandate no seepage to groundwater (liners, leak detection). • Tailings dams need NV State Engineer approval (dam safety). • Closure: detoxification of heaps, evaporation or treatment of tailings water. • Innovative recycling (e.g. reprocessing heaps) treated as mining activity (needs permits).	• Similar to others: tailings facilities require design approval if high hazard (State Engineer dam safety). • Utah DEQ may set groundwater protection rules for tailings seepage. • All tailings must be covered or removed per reclamation plan (Utah emphasizes returning land to stable condition).	• Tailings dams, rem certification, stringen are centerline or do lessons from Canada • DEC may require tailings supernatant d • Long-term monit impoundments is assurance must maintenance.

Table 1: Comparison of Key Mining Waste Regulatory Requirements (Federal vs. Selected western USA States).

Arizona

Arizona is one of the top mining states in the U.S., known especially for copper production. Much of its mining occurs on federal lands or involves federal permits, but Arizona law adds additional layers (table 1; figure. 1). The state has no direct analogue to NEPA (no comprehensive state environmental review statute for private projects), yet environmental regulation is vigorous through specific permits. The Arizona Department of Environmental Quality (ADEQ) administers programs under the Clean Water and Clean Air Acts. For example, any discharge of pollutants from mine sites to water requires an Arizona Pollutant Discharge Elimination System (AZPDES) permit (Arizona is authorized to implement CWA permitting). Uniquely, Arizona uses an Aquifer Protection Permit (APP) system to protect groundwater: mines must obtain an APP for facilities like tailings impoundments or heap leach pads that have potential to seep pollutants to groundwater. The APP process often dictates the design of tailings facilities, requiring liners, leachate collection, and monitoring to meet groundwater quality standards. This effectively regulates tailings storage even though tailings are exempt from federal hazardous waste rules. In addition, Arizona's Department of Water Resources oversees dam safety, including the safety of tailings dams, through state dam safety statutes.



The Figure:1

Figure. 1 Distribution of mapped mine features and mineral occurrences across Arizona, shown within a statewide extent (dashed outline). Black symbols represent documented mine locations and prospects compiled in the Arizona Geological Survey mineral resources database, illustrating dense clustering within historically productive districts of the Basin and Range Province, the Transition Zone, and along the margins of the Colorado Plateau. The map provides regional context for the spatial relationship between mining activity, physiography, and major structural provinces across Arizona. Data source: Arizona Geological Survey, ArcGIS Map Viewer mineral resources layer: (https://www.arcgis.com/apps/mapviewer/index.html?layers=a56d426f8cc4454fa1d0fdb1a82c9ea3)

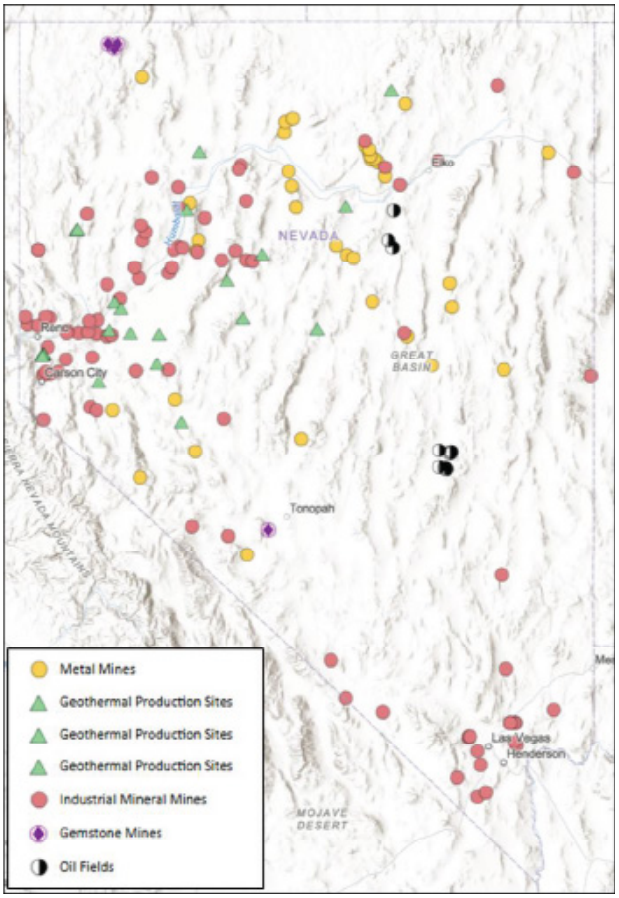
Land and reclamation regulation in Arizona involves the State Mine Inspector's Office (ASMI). Arizona's Mined Land Reclamation Act (A.R.S. §27-901 et seq., enacted in 1996) requires that mining operations on private lands (and state trust lands) submit a reclamation plan to ASMI and obtain approval for closure measures [5]. All mines on private/state land disturbing ≥5 acres must have an approved reclamation plan and must post a financial assurance to ensure reclamation is completed. (On federal lands in Arizona, reclamation is enforced by the federal agencies and parallel bonding is usually required by BLM; ASMI defers to those plans on federal land, but on private land the state takes primary responsibility.) The Arizona State Mine Inspector also has a public safety mandate, to inventory and close off dangerous abandoned mine openings and to enforce mine safety regulations (though day-to-day worker safety is federal MSHA's role).

Permitting process in Arizona often involves both state and federal steps. A large new mine might require: a Plan of Operations and NEPA review by federal agencies if on federal land; state air and water permits from ADEQ; a reclamation plan from ASMI if on private/state land; water rights or groundwater withdrawal permits from state agencies; and local county or municipal zoning approvals or ordinances. Historically, county governments in Arizona have had limited say ("preemption" by state law can limit local bans on mining), but they do control land use planning to an extent. Notably, in recent years conflicts have arisen between state and local authority, for example, after a federal court blocked the proposed Rosemont Copper Mine from using federal forest land for its tailings, the mining company shifted plans to use adjacent state-owned land for tailings. This was possible because the Rosemont court decision (2019) interpreted the 1872 Mining Law to not allow waste dumping on unclaimed federal land, an interpretation not binding on state land. Arizona's authorities (State Land Department for state trust lands) then leased land to the company to accommodate tailings, a move that avoided the federal restriction [1]. This case (now called the Copper World project) exemplifies how Arizona can facilitate mining by utilizing state land and how state-level decisions can be pivotal when federal law presents obstacles. It also highlighted public concerns, tribes and local communities opposed the mine due to impacts on sacred sites and water, leading to ongoing legal battles [1,2].

Public engagement in Arizona's mining projects primarily comes via the federal NEPA process (when applicable; figure. 6) or through public notice on state permits (ADEQ often holds comment periods for major permits like the Aquifer Protection Permit). Arizona does not require a public hearing for the state reclamation plan approval itself, but information is generally accessible. The state has also been active in identifying mining-related critical mineral opportunities. For instance, Arizona is exploring recovery of scandium and rare earths from historic mine tailings and smelter waste; the state's rich mining heritage means large volumes of residues that might contain strategic metals. The policy challenge for Arizona is balancing its pro-mining economic stance with the environmental constraints of its arid climate (where water is scarce and tailings dust or seepage can have outsized impacts). In summary, Arizona leverages federal processes for big projects but has robust state mechanisms for environmental protection and reclamation on non-federal lands, with the State Mine Inspector ensuring that private land mining operations cannot simply be abandoned without reclamation [5].

Nevada

Nevada leads the United States in gold production and has a well-developed regulatory regime often cited as industry-friendly but effective (table 1; figure. 2). Approximately 85% of Nevada's land is federal, so federal laws (1872 Mining Law, BLM/USFS regs, NEPA, etc.) strongly influence Nevada's mining projects. However, Nevada has comprehensive state requirements that apply to all mining operations within its borders, whether on federal or private land. The Nevada Division of Environmental Protection (NDEP), within the Department of Conservation and Natural Resources, houses the Bureau of Mining Regulation and Reclamation (BMRR) which is the key state regulatory body for hardrock mining. Nevada law (NRS 519A) mandates that any mining or exploration operation exceeding 5 acres of surface disturbance must obtain a state Reclamation Permit before commencing work [11]. To get this permit, the operator submits a reclamation plan detailing how the site will be reclaimed (including addressing tailings, heaps, waste rock dumps, pit closure, etc.), and posts a reclamation bond or other financial assurance with the state [11]. The Nevada reclamation regulations set standards similar to federal requirements, e.g. stable re-contoured landforms, removal or isolation of harmful materials, revegetation, and protection of water resources. Small operations below 5 acres are exempted from the full permit but still must reclaim and file a notice.



The Figure:2

Figure. 2 Distribution of major resource extraction and energy sites across Nevada, showing metal mines (yellow circles), industrial mineral mines (red circles), gemstone mines (purple diamonds), geothermal production sites (green triangles), and oil fields (black symbols). The map highlights the spatial association of mining and energy infrastructure with Nevada's Basin and Range physiography, including concentrations near major population centers (e.g., Reno–Carson City and Las Vegas) and along structurally controlled trends within the Great Basin. Data source: Nevada Mineral Explorer (Nevada Bureau of Mines and Geology), accessed via ArcGIS Experience Viewer: https://experience.arcgis.com/experience/b285a244becd45f5b81119ddfe85bbdb/

In addition to reclamation permits, Nevada requires stringent Water Pollution Control Permits for mining facilities. Under state regulations (NRS 445A, NAC 445A), any process component that can discharge to the environment, such as tailings impoundments, processing ponds, heap leach pads, and waste rock yards, must operate under a water pollution control permit that ensures no degradation of waters. Practically, this means Nevada BMRR reviews the design of tailings dams and heap leach pads to ensure they have liners, seepage controls, and monitoring wells; the state might require Best Available Technology to minimize any seepage. These permits include detailed operating plans, spill contingency plans, and closure plans (for example, requiring that tailings facilities be drained, capped, and secured at closure, and heap leach piles rinsed or treated to remove residual chemicals). Notably, Nevada's emphasis on containment stems from its groundwater protection laws, even though much of Nevada is desert with deep water tables, the law protects all groundwater as potential future resource, so mines must not contaminate aquifers above certain standards. Nevada is also unique in having a Mercury air emissions program for precious metal mines (since heap leaching and furnaces can release mercury), in cooperation with EPA. This was one of the first state-level mercury control programs for gold mining.

Coordination with federal agencies is routine in Nevada. For instance, when a mine on BLM land is proposed, the company will submit a Plan of Operations to BLM and a Reclamation Permit application to NDEP simultaneously. The agencies conduct joint reviews and often produce a single reclamation cost estimate using a standardized model (Nevada developed the SRCE, Standardized Reclamation Cost Estimator, BLM also uses; [11]. A single reclamation bond is then posted that names both BLM and the State as beneficiaries, covering obligations to both [5]. This avoids duplication and is facilitated by an MOU between BLM and NDEP. NEPA reviews in Nevada also commonly involve state participation, and public meetings for an EIS in mining towns like Elko or Winnemucca are jointly attended by state officials.

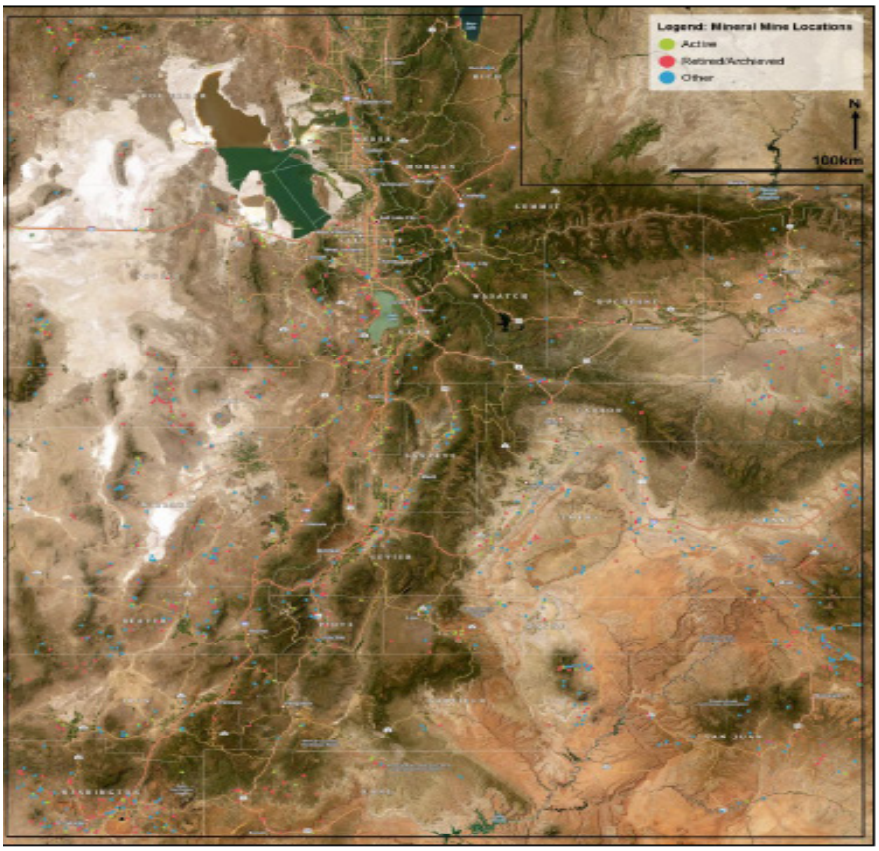
Nevada does not have a state EIS law, but certain projects might undergo public land use hearings at the county level (county commissions consider special use permits for aspects like expansion of mining onto private lands). Generally, rural Nevada counties are supportive of mining, and the state's policy explicitly encourages mining as beneficial to the

economy. Nevertheless, Nevada has environmental safeguards: for example, Nevada law prohibits approval of a mine that would result in "formation of a permanent lake on the pit floor that will degrade ground water" beyond certain limits (this addresses pit lake water quality after mining). If a pit lake is predicted to have poor water quality, the operator must treat or mitigate it, or Nevada may deny the plan [12].

One of Nevada's challenges has been dealing with abandoned mines, especially old milling sites with mercury contamination (e.g., the Carson River Mercury Superfund Site from 19th-century Comstock mining). The state has an active Abandoned Mine Lands program (focused on securing old mine shafts for public safety), but environmental remediation often involves federal Superfund. However, Nevada will likely benefit from the 2024 Good Samaritan law by facilitating cleanup of some historic mining areas by third parties. On the innovation front, Nevada is a hotbed for tailings reprocessing research, for example, reprocessing old heap leach pads to recover additional gold or exploring extraction of lithium from clay tailings. The regulatory approach treats these as mining projects: reprocessing an old heap or tailings storage in Nevada still triggers the requirement for a reclamation permit and water pollution control permit (since process fluids or material movement is involved). If anything, Nevada's framework is conducive to such projects because the permitting is well-defined and the state has experience with mining and closure of large, modern mines. In summary, Nevada's system is characterized by clear requirements for reclamation and water protection (permits for >5 acres, mandatory bonding; NDEP, 2025), a close partnership with federal regulators, and a track record of adapting rules (like mercury emission controls, pit lake policies) to emerging issues [11]. It remains one of the most active jurisdictions for hardrock mining regulation in the U.S.

Utah

Utah's mining industry ranges from world-class copper and beryllium operations to numerous small mines for industrial minerals (table 1; figure. 3). The Utah Division of Oil, Gas and Mining (DOGM) regulates mining on all lands in the state except federal operations are subject to federal approval in addition. Utah's approach is in line with western state norms: any person wanting to conduct non-coal mining must obtain a state Minerals Permit and file a Notice of Intention to Conduct Mining or Exploration. Under the Utah Mined Land Reclamation Act (Utah Code Title 40-8), all mining operations must be reclaimed and reclamation surety (bond) posted (DOGM, 2012). Utah's rules (Admin. Code R647) distinguish exploration, "small mining" (disturbing <5 acres in a year), and "large mining" (≥5 acres). Small mines file a simplified notice and reclamation plan (with bond), while large mines require a detailed Notice of Intention including environmental baseline information, an operating plan, and a reclamation plan. DOGM reviews these plans for compliance with performance standards (stabilizing tailings, preventing erosion, revegetation, etc.) and coordinates with other agencies. Notably, even if a mining project is undergoing federal NEPA review, Utah still requires its own permit, but DOGM will often accept a combined environmental document to satisfy information needs. Utah law mandates that reclamation achieve a stable condition with no unacceptable water pollution and that all mine waste is adequately contained. Bonds are not released until DOGM is satisfied that reclamation is successful (with a liability period of a few years to ensure vegetation regrowth) [13].



The Figure:3

Figure. 3 Distribution of mineral mine locations across Utah, overlaid on a satellite basemap to provide physiographic and infrastructural context. Colored symbols indicate mine status, including active operations (green), retired or archived sites (red), and other or unspecified mine records (blue). Mine locations are widespread across the Basin and Range, Wasatch Front, and Colorado Plateau provinces, with notable clustering in historically productive districts of western Utah, the central Utah mineral belt, and southeastern Utah. The figure illustrates the spatial relationship between legacy and active mining infrastructure, major transportation corridors, and regional geology. Data source: Utah Automated Geographic Reference Center (AGRC) / Utah Geological Survey mineral mine locations, accessed via ArcGIS Map Viewer (https://www.arcgis.com/apps/mapviewer/index.html?webmap=0f1872faa90f45d7b0ff0b72fd448437).

Environmental permits in Utah are handled by the Utah Department of Environmental Quality (DEQ). Mines must obtain Utah Pollutant Discharge Elimination System (UPDES) permits if they discharge to surface waters (though many Utah mines are zero-discharge). If a tailings impoundment or heap leach could affect groundwater, a state groundwater discharge permit may be required (similar to Arizona's APP concept, Utah requires demonstrating that any leachate will meet groundwater protection levels at compliance boundaries). Utah also enforces air quality regulations for mines (for dust, diesel generators, etc., through DAQ permits). The state's water rights system means large mines that use or dewater water need water rights approved by the State Engineer. Additionally, Utah's Division of Water Rights has a Dam Safety section that would oversee any tailings dam that meets size criteria, ensuring design approvals and regular inspections.

One distinctive aspect is Utah's support for mineral exploration and development through incentives. In 2022, Utah created a state Mineral Exploration Tax Credit to encourage companies to explore for critical minerals and metals [14]. This reflects a strategic interest in discovery of resources like lithium, rare earths, or others within Utah. Such incentives complement the regulatory regime by lowering costs for early-stage projects that will later go through permitting. Utah has also engaged in research partnerships (e.g., the University of Utah working on extraction of critical minerals from coal combustion ash and associated mining wastes).

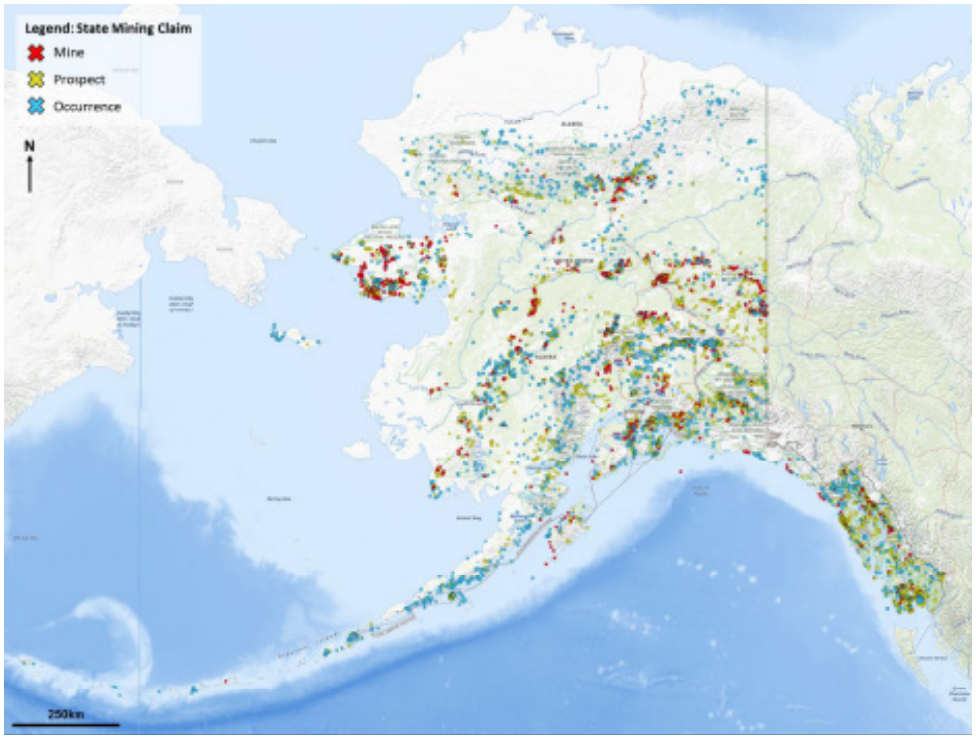
Public involvement in Utah's mine permitting is somewhat limited in formal statute; there is no broad public hearing required for a DOGM permit unless the agency or board finds it in the public interest. However, large or contentious projects often become public: for example, the expansion of the Rio Tinto Kennecott Bingham Canyon mine (the largest open-pit copper mine in the U.S., located in Utah) has been subject to public scrutiny especially regarding its massive waste rock dumps and historical tailings. The Utah Board of Oil, Gas, and Mining (a citizen board overseeing DOGM) holds public meetings where significant permits or policy changes can be debated, and stakeholders (including environmental groups and local residents) have the opportunity to comment or appeal decisions.

Utah's regulations require interagency coordination particularly for environmental issues. DOGM will consult with Utah DEQ on water quality matters and with the Division of Wildlife if wildlife habitat could be affected (Utah has some sage grouse habitat issues, for example). On federal lands, DOGM may become a cooperating agency in NEPA. An example of coordination is the Lisbon Valley copper mine (on a mix of private and federal land) where DOGM, BLM, and EPA all had roles in permitting a novel in-situ recovery experiment; the project required aligning state groundwater protection requirements with federal land use authorizations.

In sum, Utah's framework ensures that no mine operates without a state reclamation plan and bond in place, and that mine wastes are handled to prevent pollution. It perhaps flies under the radar compared to Nevada or Arizona, but Utah's consistent enforcement of reclamation (it holds over 600 reclamation bonds for various operations has meant that modern mines in Utah proceed with relatively few major environmental incidents [14]. A future point of focus will be how Utah handles the eventual closure of Bingham Canyon's enormous tailings impoundment in the Salt Lake Valley, and whether new critical mineral projects (e.g., utilizing salt flat brines for lithium or reworking old uranium piles) will be facilitated under existing law or require new regulations.

Alaska

Alaska's mining environment is unique, it contains world-class base metal mines (such as Red Dog zinc mine), gold mines, and proposed large projects (like the Pebble copper-gold prospect), often in remote areas with sensitive ecosystems (salmon fisheries, wilderness) and significant involvement of Alaska Native tribes and corporations (table 1; figure. 4). Alaska has built a rigorous but somewhat centralized permitting system to handle this complexity. Key is the concept of the "Large Mine Permitting Team." For any major mine development, Alaska's Department of Natural Resources (DNR) assembles a project team pulling together all relevant state agencies, DNR (land and water management), the Department of Environmental Conservation (DEC, handling water and air permits), Department of Fish & Game (fish habitat permits), and others, to review the project in a coordinated fashion. The applicant submits a Plan of Operations and a Reclamation Plan to DNR, and typically a single Multi-Agency Permit Application (the APMA, as mentioned earlier) that serves as a consolidated application for various permits. This one-stop approach is possible because many Alaska mines are on state land or involve state permitting at multiple levels.



The Figuer:4

Figure. 4 Distribution of state-recorded mining features across Alaska, including documented mines (red symbols), prospects (yellow symbols), and mineral occurrences (blue symbols). The map illustrates the broad spatial extent of mineral exploration and development across Alaska, with dense clusters along the Brooks Range, Seward Peninsula, Interior Alaska, the Alaska Range, and the coastal belts of southeastern Alaska. This statewide compilation highlights Alaska's significant mineral endowment and the dispersion of both historic and modern exploration targets across diverse geologic provinces. Data source: Alaska Division of Geological & Geophysical Surveys (DGGS)/State Mining Claims and Mineral Occurrences, accessed via ArcGIS Experience Viewer (https://experience.arcgis.com/experience/27bee3d0631345dba0f02653b74e92c6)

Alaska law (AS 27.19, the Alaska Surface Mining Reclamation Act) requires reclamation for all mining operations regardless of land ownership [15]. Before mining on any land (federal, state, or private) in Alaska, a reclamation plan must be approved by the state, unless the disturbance is below a minimal threshold [15]. Small operations under 5 acres need only file a Letter of Intent to reclaim and an annual statement, but larger operations (≥5 acres) must submit a detailed reclamation plan and provide a financial assurance (either by participating in the statewide Reclamation Bond Pool or posting an individual bond; CCSI, 2025) [15]. This requirement is comprehensive, even a miner with an approved federal Plan of Operations on BLM land must also get the state's reclamation plan approval (after getting BLM's, since BLM's approval is needed first in that case; CCSI, 2025) [15]. The state plan will cover how tailings and waste are handled, sediment control, and rehabilitation of the site. The bond pool is an interesting option Alaska provides especially to small mines: rather than each small miner getting an expensive surety bond, they can pay fees into a collective pool managed by the state, which can cover reclamation if any participant defaults. Large mines, on the other hand, usually provide site-specific bonds in the tens of millions of dollars (for example, the Fort Knox gold mine near Fairbanks has a sizable bond for its tailings dam and heap leach closure obligations). Alaska also has specific financial assurance for long-term water management: if a mine will require post-closure water treatment or tailings dam monitoring in perpetuity, the state can require a trust fund or other long-term funding mechanism to be established (this was seen in the permits for the Greens Creek mine tailings facility).

Environmental regulation in Alaska involves both state and federal players. DEC issues permits for wastewater discharges (Alaska has primacy for CWA Section 402 permitting), however, in practice many mines in Alaska do not discharge directly to streams; instead, they may treat water and infiltrate or use other methods. DEC also issues air quality permits (for mines with generators, crushers, etc.) and oversees solid waste disposal (any waste management facility like a tailings storage on state land needs a DEC solid waste permit). Dam safety is taken very seriously in Alaska after high-profile dam failures in neighboring Canada. Alaska's Dam Safety Program (within DNR) requires that any tailings dam be designed by a professional engineer to meet stringent criteria and that it obtains a Certificate of Approval to Construct and Operate a Dam. After construction, annual inspections and safety reports are mandatory. Alaska updated its dam safety regulations post-2014 to include new requirements specifically for mine tailings dams, particularly for closure, for instance, regulations now mandate detailed closure plans for tailings dams and possibly financial assurance that extends until the dam is demonstrably stable long-term [16]. As a result, modern tailings facilities like the one at Red Dog or Fort Knox are engineered to high standards and closely monitored.

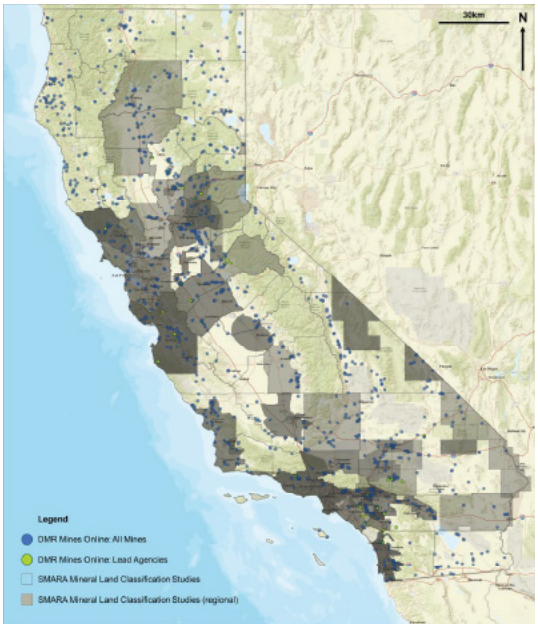
Public and tribal engagement are critical in Alaska. Large mine projects (e.g. the proposed Pebble Mine in the Bristol Bay watershed) have prompted extensive public comment periods and tribal consultations. While a project on state land in Alaska does not trigger NEPA (no federal action if entirely on state/private land), the state often voluntarily undertakes NEPA-like reviews for the biggest projects or those requiring federal wetlands permits (which do trigger NEPA via the Army Corps). For example, the Donlin Gold project (on a mix of federal and Native corporation land) underwent a full EIS by the Corps, and the state agencies participated and also responded to the intense public input, especially from indigenous communities concerned about subsistence resources. The state's public notices and subsistence hearings are important for complying with Alaska laws that protect subsistence fishing and hunting for Native villagers.

Unique to Alaska is the role of Native Corporations. Pursuant to the Alaska Native Claims Settlement Act (1971), regional and village Native corporations own significant land, including areas with mineral potential. They have their own agreements and often partner with mining companies (as at the Red Dog mine, which is on lands owned by the NANA Regional Corporation and leased to Teck). These corporations bring another regulatory layer; they require mining on their land to meet not just state regulations but also the terms of agreements (which often include robust environmental and cultural safeguards and oversight committees).

In summary, Alaska's regulatory framework is comprehensive and coordinated: all mines big and small need state reclamation approval and bonding; large mines go through a multi-agency review that integrates state and federal requirements; and the state has pioneered strong tailings dam safety oversight [15]. The tensions in Alaska revolve around protecting its clean water and fisheries from acid mine drainage or tailings failures, hence the state's careful approach in recent years, even denying or conditioning some permits (as seen when the Pebble Mine's key federal water permit was denied in 2020 under CWA 404). Going forward, Alaska is looking at opportunities to extract critical minerals like rare earth elements from its coal and mineral wastes (the state's Critical Minerals Strategy identifies such prospects), but any such projects will face the same rigorous scrutiny to ensure Alaska's environment and communities are not negatively impacted.

California

California's mining regulations (table 1; figure. 5) reflect the state's broader environmental stringency and strong local governance. Although California is not as dominant in hardrock mining today as Nevada or Arizona, it has numerous active operations (gold, industrial minerals, construction aggregates) and significant potential for lithium (in desert brines and clays) and other critical minerals. The cornerstone of California's mine regulation is the Surface Mining and Reclamation Act (SMARA) of 1975 (Public Resources Code §§2710 et seq.), one of the first state laws in the nation to require environmental review and reclamation for virtually all mines. SMARA applies to any surface mining operation that disturbs more than 1 acre or 1,000 cubic yards of material (SMARA, 2025). It requires that no mining can commence without: (1) an approved Reclamation Plan, (2) a financial assurance for reclamation, and (3) any other required local land use permit [17]. In California, local county governments (or city governments) act as the "lead agency" for SMARA, meaning a mining company must get a permit (often a conditional use permit) from the county, which includes approval of the reclamation plan. This process inherently involves local public hearings and environmental assessment under the California Environmental Quality Act (CEQA). CEQA, enacted in 1970, is a state law analogous to NEPA that requires environmental impact analysis and mitigation for discretionary projects. For a new mine, the county (or sometimes the State if it has jurisdiction on certain lands) will be the CEQA lead agency, preparing either an Environmental Impact Report (EIR) or negative declaration. Public comments are solicited, and the project can face substantial opposition or legal challenges under CEQA if impacts to air, water, biodiversity, or cultural sites are not fully mitigated.



The Figure:5

Figure. 5 Spatial distribution of mining activity and mineral land classification studies across California. Blue points show all active and historic mines recorded in the California Department of Conservation's Division of Mine Reclamation (DMR) Mines Online database, with green points highlighting mines for which DMR serves as the lead regulatory agency. Shaded polygons delineate areas covered by SMARA Mineral Land Classification (MLC) studies, including both detailed site-specific studies and broader regional assessments, which identify lands containing significant mineral resources of statewide or regional importance. The map illustrates the strong concentration of mining activity within classified mineral resource areas, particularly along the Sierra Nevada, Coast Ranges, Mojave Desert, and southern California. Data source: California Department of Conservation, Mines Online Map Viewer: (https://maps.conservation.ca.gov/mol/).

SMARA's requirements ensure that even if a mine is on federal land, the portion of surface mining activities in California must have an approved reclamation plan meeting state standard. In practice, many mines in California are on private or state lands, so SMARA is the primary regulatory tool. Reclamation plans under SMARA must detail how the mine will be closed, how tailings or waste will be disposed or neutralized, final land contours, re-vegetation schemes, and how water quality will be protected. The state has minimum performance standards (California Code of Regulations Title 14, §3700-3713) that include preserving topsoil, preventing pollution, stabilizing tailings dams, etc. The California Department of Conservation's Division of Mine Reclamation (DMR) oversees and audits local implementation of SMARA. DMR reviews reclamation plans and financial assurances that local agencies approve, to ensure they meet state requirements [17]. The State Mining and Geology Board can step in if a local agency is not properly enforcing SMARA.

One notable aspect in California is that financial assurances for reclamation can include not just bonds and letters of credit, but also corporate self-tests (if criteria are met) or trusts, and they must be capable of funding a third party to conduct reclamation. Every year, mine operators in California also file reports and pay fees to the state, and their operations are inspected to confirm compliance [17]. Idle mines (no production for a period) must get an interim management plan or else risk forfeiting permits.

From an environmental compliance perspective, California imposes additional requirements beyond SMARA/CEQA. The State Water Resources Control Board and regional water boards regulate discharges to water and can issue Waste Discharge Requirements for mine waste facilities (even for discharges to land, like tailings percolation). Also, if a mining project will use cyanide or other chemicals, the regional boards may impose specific monitoring. California's Air Resources Board and local Air Quality Management Districts set strict limits on dust (PM10) and engine emissions, for example, mines in California's desert might need robust dust control to avoid affecting air quality in nearby communities or violating standards. Furthermore, California's toxic materials laws (such as Proposition 65) can come into play if mining operations could lead to public exposure to listed carcinogens or reproductive toxins (like airborne arsenic from tailings dust).

Public engagement in California is robust. Virtually all mining proposals go through multiple public hearings (planning commission, Board of Supervisors, etc.) and can be appealed. Environmental NGOs and community groups are active, often using CEQA lawsuits to challenge mines they view as harmful (there have been cases blocking proposed gold mines on CEQA or land use grounds, or requiring major revisions). On the other hand, California also recognizes the need for local materials (aggregate for construction is a big driver), and SMARA includes a policy to ensure the production and conservation of mineral resources [17]. The state identifies Aggregate Resource Areas and tries to prevent their sterilization by urban development.

With respect to tailings reprocessing and critical minerals, California shows interest but also caution. For example, the Mountain Pass rare earth mine in eastern California (the only rare earth producer in the U.S.) had historical environmental issues with radioactive wastewater. When it restarted in the 2010s, it did so under heavy state oversight to ensure tailings (which contain some thorium) were properly managed. Today's push for lithium has California supporting projects like the extraction of lithium from geothermal brines in the Salton Sea region, a process that will create waste streams that must be regulated. The state formed a Lithium Valley Commission to recommend regulatory strategies for this new industry. In a circular economy context, California has many legacy mine sites (from Gold Rush-era mercury-laden gold tailings in the Sierras to asbestos mines) that could be candidates for remediation and resource recovery; the state's Superfund-equivalent laws and toxics control laws will govern any such efforts alongside the new federal Good Samaritan provisions.

In summary, California's regulatory regime is perhaps the strictest in the U.S., requiring local community approval and thorough environmental mitigation for mining projects. SMARA ensures no mine is left unreclaimed (financial assurances guaranteed), and CEQA provides a powerful tool for assessing and mitigating environmental harm [17]. While this can lengthen and complicate permitting (mines in California often face multi-year approval processes and litigation), it also aligns with California's broader climate and conservation goals. For mining companies, California's process demands early and comprehensive planning for tailings and waste management and extensive engagement with stakeholders to successfully navigate the permitting gauntlet.

Comparative Permitting Procedures and State-Federal Regulatory Overlays

The foregoing state case studies illustrate both commonalities and differences in mining and tailings regulation. All major mining states require reclamation plans, bonding, and various environmental permits, but the stringency and processes vary. Table 1 provides a comparative summary of key regulatory aspects across the federal level and selected states (Arizona, Nevada, Utah, Alaska, California):

This comparison highlights that while all jurisdictions seek to minimize environmental impacts and ensure reclamation, the degrees of public involvement and upfront planning differ greatly. California stands out for its rigorous environmental impact analysis and local permit hearings for essentially every mine, whereas Nevada and Arizona rely more on technical agency reviews and federal NEPA for public disclosure. Alaska and California demand comprehensive bonding and closure planning even for long-term post-closure needs, whereas others handle perpetual water treatment funding on a case-by-case basis. On critical minerals, federal policy is clearly pushing reprocessing of mine waste, and states are generally receptive but have not all created dedicated programs yet, though Utah's tax credit and Nevada's facilitation of lithium projects indicate movement in that direction.

Another notable point is how states layer their requirements on top of federal law. For example, even though the 1872 Mining Law does not require royalties or robust environmental protection, states like Nevada impose state "net proceeds" taxes or severance taxes on minerals, functioning similarly to royalties [2]. Most western states have such taxes that generate revenue from mining to support local governments or reclamation funds. Likewise, in absence of a federal hardrock abandoned mine land fee (like coal has), some states use their general funds or creative approaches (e.g. Nevada's AML fee on claim holders) to tackle legacy mine hazards.

In practice, a mining company must comply with both federal and state permits, this means a project can only go as fast as the slowest approval. Interagency agreements (e.g. joint EIS, joint bonding) help to prevent contradictory requirements and reduce duplication, but they do not eliminate the need to obtain every permit. If any one agency denies a key permit (for instance, a state water quality certification or a federal 404 wetlands permit), the project cannot proceed. Thus, effective coordination and stakeholder engagement early in the process are crucial to identify and address concerns that could jeopardize a permit.

Policy Challenges and Opportunities

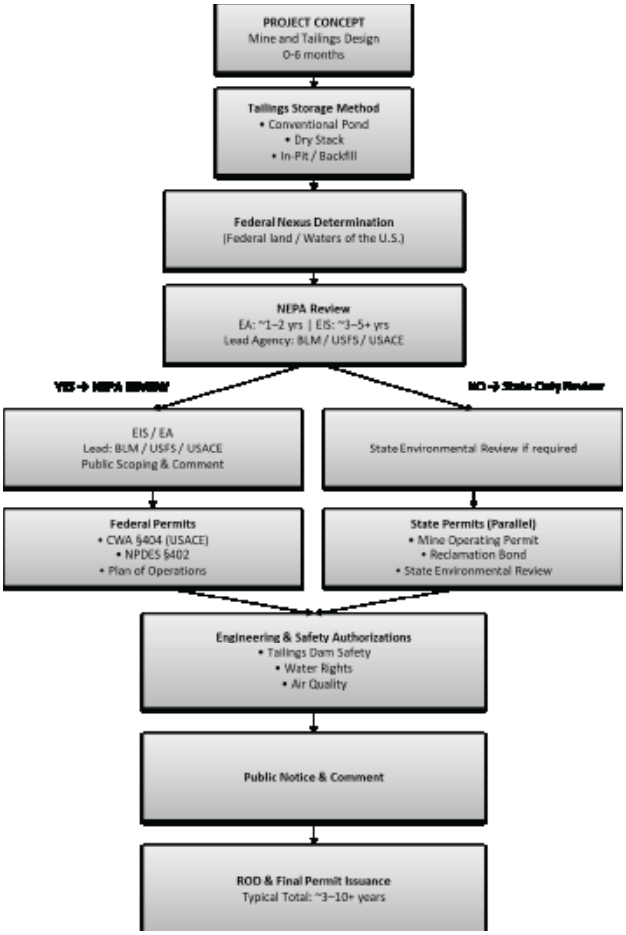
Managing and reprocessing mine tailings and waste in the U.S. today sits at the nexus of environmental responsibility, regulatory reform, and the drive for critical minerals. Several challenges hinder the swift deployment of innovative, sustainable mining practices:

Outdated Statutory Framework

The General Mining Law of 1872, with its lack of royalties and minimal environmental provisions, remains unreformed [1]. This not only forfeits potential funding for reclamation (unlike coal mining, which via SMCRA generates fees for an AML fund) but also symbolizes the difficulty of updating mining policy. Efforts to amend the law (for instance, to add a federal hardrock royalty or to mandate modern environmental standards) have repeatedly stalled [3]. The result is that federal land managers must use workarounds, like requiring mitigation measures through FLPMA regulations or relying on state laws, rather than having a comprehensive modern mining code. Legislative inertia thus keeps in place a patchwork approach that can leave regulatory gaps or inequities (e.g., tribal lands and sacred sites are often not well-protected under the old law, leading to conflicts like the Oak Flat/Resolution Copper dispute in Arizona [2].

Complex, Lengthy Permitting Processes

As described, a major mining project can take 3-10 years (figure. 6) to permit due to sequential and overlapping reviews. NEPA EIS processes, while crucial for transparency, often span years (though recent reforms aim to shorten this) [2]. Multiple permits create potential "bottlenecks" [1]. The 2025 federal push to "identify priority projects that can be immediately approved" and expedite permits acknowledges this concern [1]. However, fast-tracking can trigger public distrust if it appears to cut corners on environmental protection or community consultation [11]. Thus, regulators must balance efficiency with due diligence. Some states have tried to streamline internally (e.g., Alaska's APMA one-stop application, Nevada's coordinated BLM-state bond process), but interagency coordination nationwide is inconsistent. Mines that cross state/federal jurisdictional lines face extra complexity (for instance, a mine plan partly on federal land and partly on private land in California might require both an EIS and a CEQA EIR, two similar but not identical processes).



The Figure:6

Figure. 6 Conceptual flowchart illustrating the typical U.S. permitting and review pathway for mine and tailings facilities. The diagram shows progression from early project concept and tailings storage design through federal nexus determination, NEPA environmental review (EA or EIS), parallel federal and state permitting, engineering and safety authorizations, public notice and comment, and final Record of Decision (ROD) and permit issuance. Indicative timelines highlight that full approval commonly requires ~3–10+ years, depending on project complexity, jurisdiction, and regulatory scope.

Environmental and Safety Risks

Catastrophic tailings dam failures globally have raised awareness that traditional tailings management carries high stakes. In the U.S., many tailings facilities are aging or were built to older standards; ensuring their safety (especially against earthquakes or extreme weather) is a challenge. Regulators and industry are gradually moving toward better practices (e.g., using filtered tailings or buttressing old dams), but retrofitting safety measures to existing facilities or guaranteeing perpetual maintenance is difficult. Moreover, thousands of abandoned mine waste sites continue to leach contaminants, these are environmental liabilities that lack clearly responsible parties. The new Good Samaritan law is a positive step to mitigate this, but with only 15 pilot projects allowed initially, it will cover a tiny fraction of the estimated 500,000+ abandoned hardrock mine features in the country [7]. Funding and scaling up remediation of historical mine waste remain formidable tasks.

Liability and Uncertainty

Even with Good Samaritan protections, companies interested in reprocessing tailings for minerals must navigate uncertain regulatory definitions. For example, if a company reprocesses tailings from a site that was closed decades ago, will that trigger requirements to bring the entire site up to modern standards (which could be prohibitively expensive)? The DOI working group report in 2022 noted that re-mining mine or mill tailings could "mitigate [hazards] and recover critical minerals", but also that doing so raises questions of how to apply reclamation standards and whether prior contamination becomes the new operator's responsibility [3]. This uncertainty can deter investment in tailings reprocessing unless agencies provide clear guidance or carve-outs. The Secretary's Order 3436 seeks to clarify some of this (e.g., by saying extraction from coal waste is not "mining" under SMCRA; Annatoyn et al., 2025), but many scenarios (like hardrock tailings on federal vs. private lands) need case-by-case interpretation until formal regulations are developed [8].

Public Trust and Social License

Mining projects, especially those involving new technologies (like chemical leaching of old tailings) or located near communities, face scrutiny from the public. Past negative legacies (toxicity, Superfund sites, mine spills such as the 2015 Gold King Mine spill in Colorado) have eroded trust. Gaining community acceptance for reprocessing projects can

be as challenging as for new mines. States like California effectively give local communities veto power through political processes, whereas in states like Nevada or Arizona, the state can override local opposition to enable projects (Arizona even preempts local bans on mining by state statute in some cases) [1]. This leads to an uneven social landscape; a company may find a warm welcome in one state and staunch opposition in another for a similar project. Engaging stakeholders early, sharing benefits (jobs, improved environmental conditions), and respecting tribal and local concerns are all essential to obtaining the "social license to operate."

Circular Economy & Resource Efficiency

Despite these challenges, there are significant opportunities and positive trends in aligning mine waste policy with sustainability and innovation:

The imperative to supply critical minerals for batteries, renewable energy, and electronics is driving creative thinking. Mine tailings and waste are now viewed as potential "urban ore" or secondary sources. For example, the U.S. Department of Energy has funded projects to extract rare earth elements from coal ash and acid mine drainage sludge, and the ARPA-E MINER program is investing in technologies to recover minerals from mine tailings while sequestering carbon dioxide [18,19]. If successful, these technologies could be deployed at scale, turning environmental liabilities into assets. Policymakers are keen to facilitate this: the 2021 Infrastructure Act and 2022 Inflation Reduction Act both included funding and policy support for critical mineral projects, including those involving recycling and unconventional resources. In a regulatory sense, this is an opportunity to modernize laws, for instance, by explicitly allowing or fast-tracking permits for projects that demonstrably improve environmental conditions (a kind of regulatory fast lane for "clean mining" or remediation-linked mining).

Legislative Reform on Royalties & Funds

There is renewed discussion in Congress about establishing a federal hardrock mining royalty and using the proceeds to fund mine cleanups and community development (similar to how coal royalties and fees fund reclamation and economic revitalization in coal country). If enacted, such reform could provide dedicated resources to address tailings hazards and to invest in R&D for mine waste reprocessing. Even without full reform, incremental steps are being considered, e.g., increasing the claim maintenance fees and using that revenue for reclamation of abandoned mines [3]. For states, this could relieve some burden and create partnerships (federal-state) for tackling legacy sites.

Enhanced Standards and Best Practices

The mining industry, through organizations like the International Council on Mining and Metals (ICMM), has been adopting improved standards for tailings management (e.g. independent tailings reviews, rigorous safety audits). Regulators in the U.S. can capitalize on this by integrating these best practices into permits. Some states might update their rules to require conformance with the Global Industry Standard on Tailings Management 2020 [3]. Additionally, the U.S. Society on Dams in 2022 published a white paper with recommendations for tailings dam closure regulation, which states are considering. Such improvements, if adopted uniformly, reduce the risk of catastrophic failures and long-term pollution, which in turn makes reprocessing and remining projects less risky to approve from a regulatory standpoint [3].

Good Samaritan Pilot Success

If the initial wave of Good Samaritan projects (up to 15 allowed) proves successful, say, an NGO or company stabilizes an old tailings site, recovers some critical minerals, and measurably improves water quality with no liability fallout, it could build momentum to expand the program. Congress could then authorize a permanent, broader program removing liabilities for many more sites. This would greatly expand opportunities for public-private collaboration in mine waste cleanup. Mining companies might partner with state agencies or nonprofits to clean up historic mines, using their expertise and possibly recovering enough minerals to offset some costs. Communities and the environment would benefit from accelerated remediation, while companies get access to resources without the full expense of exploration and new mining. It's essentially low-hanging fruit for a domestic mineral supply if done right, and a win-win for remediation.

Interagency and Interstate Collaboration

The urgency of the energy transition is fostering more collaboration among agencies that historically worked in silos. The formation of interagency working groups on mining (like the DOI-led group in 2022) and interstate compacts (Western Governors' Association initiatives on abandoned mine cleanup, for example) is a positive development. They allow sharing of best practices, e.g., Alaska's approach to dam safety or Colorado's experiments with treating acid drainage using new tech can inform other states. Federal agencies are also engaging more with states to avoid duplication (FAST-41's expansion to mining is one mechanism; another is joint federal-state environmental review documents as allowed by 2023 NEPA implementing changes [2]. If these cooperative approaches continue to grow, it can reduce the friction in permitting and improve outcomes (like one coherent reclamation plan that satisfies all regulators, rather than separate, possibly inconsistent plans).

Public-Driven Initiatives and Transparency

Finally, the push for better policies is also coming from public and investor pressure. Investors now examine mining companies' ESG (Environmental, Social, Governance) performance, which includes how they handle tailings and community relations. The U.S. Securities and Exchange Commission in 2024 adopted climate and ESG disclosure rules for mining companies (though enforcement of some rules is currently uncertain), and these require companies to report

on how they manage environmental risks. This encourages companies to proactively adopt sustainable practices, beyond mere compliance. From the community side, increased transparency (for example, online databases of tailings dams, required in some jurisdictions) and stakeholder engagement processes (like community oversight boards for mines) can lead to more trust and potentially faster resolution of issues [2]. Projects that incorporate community benefits agreements or Indigenous partnership (as seen in some Alaska mines) are more likely to avoid litigation and delays.

In summary, the current policy landscape is at an inflection point: the barriers of outdated laws, complex permitting, and legacy pollution are gradually being addressed by new opportunities in law and policy that encourage reclamation, innovation, and prudent development. The balancing act for regulators is to ensure that easing regulatory hurdles for beneficial projects does not come at the cost of environmental protection. The goal of a "sustainable mining" framework is one where mining and tailings reprocessing contribute to the circular economy (by maximizing resource recovery) while leaving minimal long-term burden on the environment and communities. Achieving that will require continued adaptation of policies at both federal and state levels, learning from pilot projects and international best practices.

Conclusions

The governance of mine tailings spent ore, and mining waste in the United States has evolved from a virtually laissez-faire approach in the 19th century to a multilayered regulatory system today that seeks to protect the environment and public while supporting mineral development. Federally, the enduring General Mining Law of 1872 is tempered by modern statutes like NEPA, FLPMA, and environmental laws that impose critical checks on mining activities, requiring environmental review, mitigation of impacts, and reclamation of disturbed lands. State governments, particularly in the West, have taken active roles by establishing their own permitting regimes that often parallel or exceed federal requirements, ensuring that no mine operates without a plan for closure and financial security to implement it [2]. Case studies from Arizona, Nevada, Utah, Alaska, and California illustrate the diversity of approaches: from Nevada's coordination and technical focus, to California's stringent public oversight and environmental assessment, to Alaska's unified permitting and emphasis on protecting fisheries.

A consistent theme is the importance of permitting processes and interagency coordination in shaping outcomes. Mines must navigate federal and state agencies, and the success of a project, or a tailings reprocessing initiative, often hinges on how well these agencies collaborate and involve stakeholders. Recent policy initiatives at the national level signal an understanding that improvement is needed: the federal government is moving to streamline permitting for critical mineral projects, remove unnecessary regulatory barriers to tailings reprocessing, and inject new resources and legal tools (such as the Good Samaritan Act) to address the legacy of abandoned mine waste [2,4,8]. These changes, coupled with state-level innovations (like Utah's incentives for exploration or Nevada's updated mine closure requirements), are aligning mining regulation with the imperatives of the 21st century: securing critical minerals for high-tech and clean energy applications, and doing so in a manner consistent with environmental stewardship and social responsibility [14].

However, this review also makes clear that challenges remain. Fundamental reform of the 1872 Mining Law, to establish a royalty, to formalize modern environmental standards, and to acknowledge Indigenous rights, has yet to be realized [1,2]. The U.S. continues to rely on a complex mosaic of laws and regulations, rather than a single coherent hardrock mining code. This can lead to inefficiencies and gaps, but it also allows states to tailor solutions to their contexts. In practice, federal and state regulators have found ways to patch the gaps (through MOUs, complementary laws, and court decisions) such that, for example, large-scale irresponsible mining or indefinite abandonment of tailings is largely a thing of the past. No mine today is approved without a reclamation plan and bond, a stark contrast to a few generations ago. That said, the coming years will test whether the current framework can accommodate new mining paradigms: from re-mining old waste piles to deploying novel extraction technologies, all under heightened expectations for environmental justice and climate-conscious practices.

This review underscores the interdisciplinary nature of mining policy, touching law, engineering, economics, and community development. To foster innovation and sustainable development, regulators will need to continue updating regulations to keep pace with technology (for example, revising water quality criteria as treatment improves, or allowing experimental pilot projects under controlled conditions). They will also need to address the barriers identified, such as by clarifying the liabilities associated with tailings reprocessing and by providing incentives (financial or expedited review) for projects that offer net environmental benefits. The concept of a circular economy in mining, where wastes are continually converted to resources, is gaining traction and has been elevated in policy discussions from the White House to western state capitals [8,20]. Achieving it will require not just technical advances but adaptive governance.

In conclusion, the United States is charting a path toward more responsible and forward-looking management of mine tailings and waste. The current mix of federal oversight and state innovation provides a strong foundation, even if patchwork, to build upon. As critical mineral demand grows, there is an unprecedented opportunity to clean up legacy mine sites and recover valuable materials, essentially turning yesterday's liabilities into tomorrow's assets. Realizing this vision demands continued collaboration across agencies and jurisdictions, meaningful engagement with affected communities and tribes, and the political will to refine laws that are no longer fit for purpose. The trajectory is hopeful: with each policy tweak and each successful mine waste remediation, trust in the regulatory system can grow, paving the way for a mining sector that supports the energy transition and economic development while upholding high standards

of environmental protection and public health. The evolving policies and regulations discussed in this paper suggest that, while much work remains, the U.S. mining regulatory regime is gradually transforming to meet the challenges and opportunities of the 21st century.

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