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Mapping Socioeconomic and Environmental Data to Support Targeted Critical Minerals Exploration and Extraction

Modeling, Mapping, and Analysis Consortium (MMAC)

SUPPORTED BY

U.S. Department of ENERGY | Office of Manufacturing & Energy Supply Chains

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Charles, Yang

U.S. Department of Energy

Cleve Davis,
Rohit Venkat Gandhi Mendadhala, and
Christopher J. Forsgren

Idaho National Laboratory

Autumn Kaiser

Argonne National Laboratory

Sarah Inskeep and
Laura Supple

National Renewable Energy Laboratory

Idaho National Laboratory

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Charles Yang
U.S. Department of Energy
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Christopher J. Forsgren
Idaho National Laboratory
Autumn Kaiser

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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EXECUTIVE SUMMARY

The United States' dependency on imported minerals poses significant risks to economic stability and national security due to potential supply disruptions (Society for Mining 2022). Understanding the social issues and sensitivities associated with developing new critical mineral projects is key to understanding the actual, realizable pace of domestic critical mineral development to secure supply chains, rather than solely considering critical mineral deposit or reserve figures. This report describes a collaborative effort under the Modelling, Mapping, and Analysis Consortium, which includes the Idaho National Laboratory, Argonne National Laboratory, and the National Renewable Energy Laboratory to map mineral development potential along with key social and environmental datasets. A GIS-based web map application was developed as a preliminary tool for environmental analysis, integrating 125 geospatial data layers such as critical habitat, land ownership, economic indicators, and environmental concerns. Data were sourced from agencies like the Bureau of Land Management (BLM) and U.S. Geological Survey (USGS) and processed using GIS technology to enhance visualization and analysis.

A proposed analysis framework would identify the likely categorization of areas into high, mid, and low levels of concern based on withdrawn lands, special status species, the Economic Development Capacity Index Mining Composite Index, and the Climate and Economic Justice Screening Tool. This tool is most useful as a mechanism to screen out lands that clearly possess characteristics that make them unsuitable, or highly unlikely to be suitable, for development. While the application provides high-level, broad visualizations, it is not a substitute for detailed, more granular assessments that incorporate relevant stakeholder expertise and concerns necessary to determine if any particular area is suitable for development, nor for the environmental reviews required under the National Environmental Policy Act (NEPA) or other laws that may be applicable, such as the National Historic Preservation Act. Users should not take these initial, high-level initial screenings as final categorizations; rather, they must conduct further, more granular analyses and engage with Tribal entities and other stakeholders for comprehensive planning and to determine whether development of any particular land would be appropriate.

A case study of the Idaho Cobalt Belt in Lemhi County, Idaho, has been provided in the report to illustrate the tool's practical use. This report introduces a GIS application and framework to support stakeholders in identifying and prioritizing areas for critical mineral exploration, promoting secure supply chains, and advancing the nation's energy independence through responsible resource stewardship.

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ACRONYMS

Argonne:	Argonne National Laboratory
BLM:	Bureau of Land Management
CEJS:	Climate and Economic Justice Screening
DOE:	Department of Energy
EDCI:	Economic Development Capacity Index
EP:	Environmental Protection
ESA:	Endangered Species Act
GIS:	Geographic Information Systems
GRSG BSU:	Greater Sage Grouse biologically significant units
IBAs:	Important Bird Areas
ICB:	Idaho Cobalt Belt
INL:	Idaho National Laboratory
MESC:	Manufacturing and Energy Supply Chains
MLRS:	Mineral & Land Records System
NEPA:	National Environmental Policy Act
NREL:	National Renewable Energy Laboratory
OP:	Office of Policy (DOE)
OSTI:	Office of Scientific and Technical Information
SolVES:	Social Values for Ecosystem Services
USGS:	U.S. Geological Survey

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Mapping Support for Targeted Critical Minerals Exploration and Extraction

1. INTRODUCTION

Understanding the domestic availability of critical minerals is increasingly important for economic security and supply chain resilience. Previous analyses have examined US and international geological reserves of various critical minerals (Barlock et al. 2024). The DOE has determined its critical material list by assessing existing global mining production for critical materials (Bauer et al. 2023). However, informing forward looking critical materials policymaking and assessing potential future availability and supply requires a perspective on the timescale for bringing online new critical mineral projects. In particular, studies have found that bringing online a new critical minerals extraction project in the US can take multiple decades (Mohsen Bonakdarpour 2024). Understanding the US's opportunity and challenges when it comes to securing domestic supply of critical minerals requires disentangling factors that contribute to lengthy extraction project bring-up.

Critical minerals are necessary for powering energy infrastructure and supporting a clean energy transition. However, the extraction of critical minerals can often come into tension with social and environmental considerations, such as wildlife and ecosystem conservation, preservation of access to public lands, and respect for Tribal sovereignty and treaty rights. While the complete resolution of such conflicts may not be possible in some circumstances and may well be challenging in others, careful site selection could minimize, if not entirely eliminate, those conflicts. Where significant conflicts exist, mitigative strategies can be developed through modifying site parameters and a comprehensive understanding of local community expectations. Direct engagements can also build trust and help with reducing permitting timelines. While not every community or Tribal consideration is well-documented, there are a variety of geographical and socioeconomic data across various public sector repositories that are relevant to siting and permitting critical mineral projects. However, these datasets are distributed across multiple federal and state agencies and it is sometimes in difficult to parse formats. Recognizing this issue, the 2023 Mining Reform Interagency Working Group Report included improved data digitization and transparency as one of its recommendations (Biden-Harris Administration's Interagency Working Group on Mining Laws 2023).

This report presents a Geographic Information System (GIS) tool that pulls together over 125 geographical, environmental, and socioeconomic GIS layers into a single, open-source platform, including digitized GIS layers from U.S. Geological Survey (USGS) reports. This application acts as a foundational tool, offering a broad visualization of relevant spatial data, such as withdrawn lands and critical habitat of species listed on the Endangered Species Act (ESA). By leveraging symbology, informative popups, and dynamic visualizations, the web map enhances users' understanding of the landscape within the general area of interest. This preliminary step provides a comprehensive overview that facilitates essential preliminary assessments for targeted critical minerals exploration and extraction. It is important to note that subsequent steps, such as detailed GIS analysis, Environmental Assessments, and Environmental Impact Statements, fall outside the scope of this report and are not addressed here.

An analysis framework was developed based off these GIS layers to help inform land use and mineral security policy making and applied to cobalt reserves in a 13-state region, as well as a case study demonstrating the insights this GIS application can provide for critical mineral projects for the Idaho Cobalt Belt. This tool is meant to help policymakers assess realistic timelines for increasing domestic critical material supply, assist federal, state, and Tribal land-use managers and environmental reviewers, and guide developers towards important socioeconomic, environmental, and Tribal considerations. The GIS platform and analysis framework here are not meant to provide regulatory guidance or substitute for community and Tribal engagement. The GIS platform can be accessed at this link.

This report presents an initiative to map mineral development potential along with key social and environmental geospatial datasets. The project is a collaboration through the Modelling, Mapping, and

Analysis Consortium (MMAC) which includes Idaho National Lab (INL), Argonne National Lab (ANL), and National Renewable Energy Lab (NREL). The initiative's primary goal is to leverage geospatial data to pinpoint viable sites for resource extraction and aiding decision-making processes.

2. METHODOLOGY

The GIS web map application includes 125 data layers, summarized by broad thematic categories in Table 1.

Table 1. Number of GIS layers displayed in the web map application.

Major Category	Theme	Number of Layers
Proposed Analysis Framework		
	Argonne Economic Development Capacity Index (EDCI) Mining Composite Index	1
	Climate Justice and Economic Screen (CJES) Concern Level	12
	Special Status Species	1
	Withdrawn Lands	4
Informational Layers		
	Argonne EDCI Capacity Areas	5
	Bureau of Land Management (BLM) Administration	1
	BLM Locatable Minerals – Authorized Interim	1
	Climate Justice and Economic Screening	13
	Federal Emergency Management Agency (FEMA) Community Resilience Challenges Index Counties	1
	INL Critical Material Data	5
	USA States	1
	Region of Interest	1
	USA Counties	1
	Grazing Administration	3
	Land Cover	4
	Right of Way	1
	Social Values for Ecosystem Services (SolVES)	5
	USGS Critical Mineral Data	8
	Wildlife Migration Corridors	2
TOTAL NUMBER OF LAYERS		**125**

The geospatial data used in the web map application were assembled from multiple sources, including BLM, INL, USGS, and other federal agencies. The data encompass a wide array of geospatial layers, including locations of critical mineral deposits (e.g., copper, nickel, cobalt, lithium, and rare earth elements), land ownership patterns, economic indicators, environmental concerns, hydrologic features, land cover, and protected areas. Each of these layers was chosen for its relevance to the project's objectives and its potential to inform site selection for critical mineral extraction.

For example, the INL Cobalt Point Data and USGS Cobalt datasets provide valuable insights into the locations of cobalt operations and deposits, which are critical for battery production and other technological applications. Similarly, the Withdrawn Lands and Special Status Species layers help identify areas with environmental or conservation concerns that could affect mineral development.

The datasets were processed and integrated by performing various data analysis steps in ArcGIS platform and were later published as web services to ArcGIS Portal which were then fed to create a comprehensive web map application. The application utilizes layered geospatial data to facilitate visualization and analysis, providing users with an interactive tool to broadly assess land suitability or potential for mineral development.

To showcase the utility of the application, the report includes screenshots and a description demonstrating its functionality for the Idaho Cobalt Belt case study. Case studies, particularly on cobalt, will illustrate the application's practical uses for identifying suitable sites for mineral extraction while considering environmental and social-economic factors.

The geospatial data foundation of the critical mineral web map application has been built upon an interagency collaborative effort and data integration process, and the application was developed to be relevant to stakeholders such as mining developers, policymakers, federal land managers, public, and the DOE. Data sources used in the web map application are available in the Data Sources page of the application.

2.1. Proposed Analysis Framework

The quest for sustainable and secure critical mineral supply chains is a multifaceted challenge, particularly within the context of the United States, where a diverse range of ecological, social, and regulatory landscapes intersect. The proposed analysis framework presented here has been crafted to guide different types of users including developers, policymakers, federal land managers, members of the public, DOE, and other federal agencies through the complex terrain of critical mineral development opportunities and challenges across 13 key states (Figure 1). Future work may expand the analysis framework to additional states.

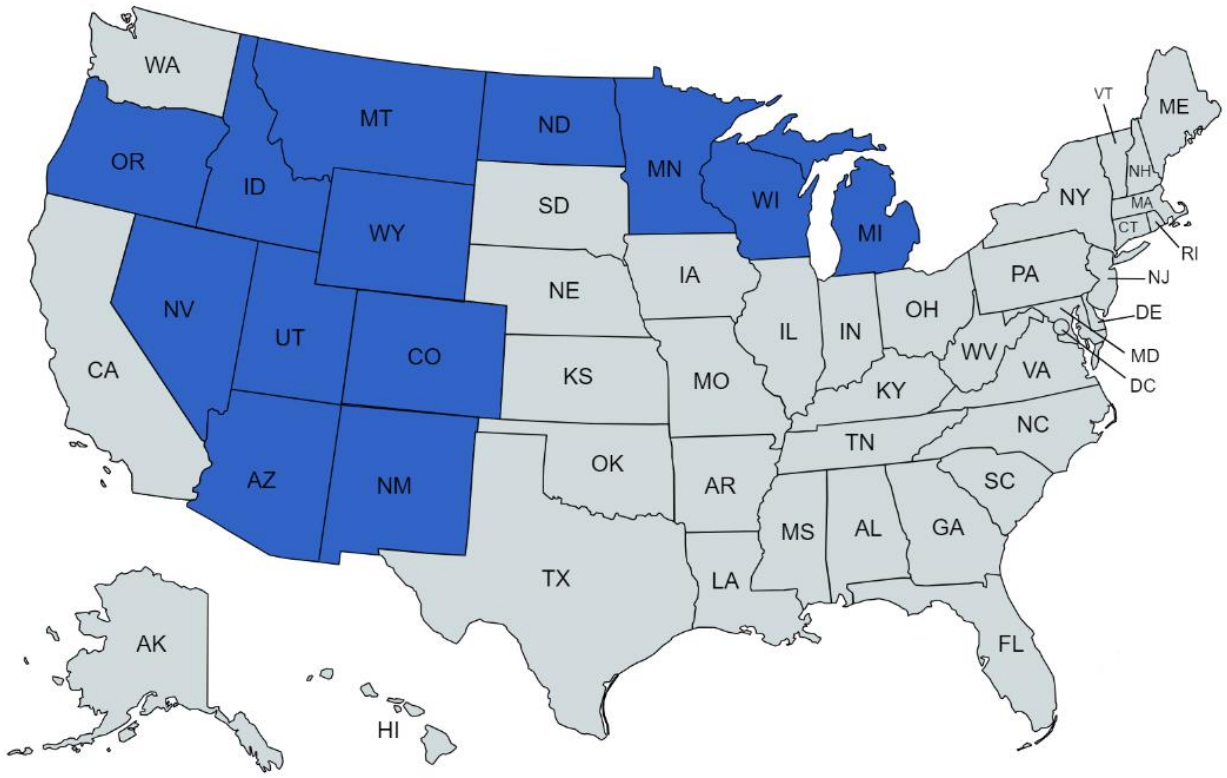

Figure 1. Map showing 13 key states (blue).

This framework is designed as an interpretive compass to navigate the intricate layers of geospatial data made accessible through the critical mineral web map application. It offers a structured approach to assess and weigh the varying degrees of development potential against environmental protection, regulatory constraints, and socio-economic considerations. Of the 125 datasets represented in the web map, a subset of indicators was evaluated for high concern, mid concern, or low concern across four categories: Withdrawn & Potential Conflict Withdrawn Lands, Special Status Species, EDCI Mining Composite Index, and CJES Concern Level.

2.1.1. Withdrawn & Potential Conflict Withdrawn Lands

Certain lands, such as those designated as Wilderness, National Parks, and National Monuments, have been withdrawn from locatable mineral entry. This unified layer consolidates all locatable mineral land withdrawals across the United States. In the context of mining, these consolidated datasets clearly highlight areas that are off-limits to mining activities. We have classified these areas as High Concern regarding withdrawals. According to the proposed analysis framework, areas in close proximity to historic sites listed in the National Register of Historic Places are also classified as High Concern due to the potential impact of mining activities on these culturally and historically valuable locations. Federal land designations categorized as Mid Concern include lands with known mineral deposits or potential for mineral discovery. These classifications, alongside designations for power withdrawals, conservation areas, recreational sites, and reclamation projects, reflect a balance of land uses that support both conservation and resource development goals. However, the Mid Concern dataset highlights the potential where critical mineral mining activities could conflict with other designated land uses, which may necessitate careful consideration of environmental impacts, legal constraints, and management practices.

2.1.2. Special Status Species

GIS datasets related to special status species that could impact the siting or permitting process of a mining project were sourced from the National Audubon Society Important Bird Areas (IBAs), the Bureau of Land Management Greater Sage Grouse biologically significant units (GRSG BSU), and the United States Fish and Wildlife Service and National Marine Fisheries Services' Critical Habitat for Threatened and Endangered Species. High Concern indicates the presence of designated critical habitats for species that are listed under federal law or proposed for listing. Mid Concern indicates the presence of Greater sage grouse biologically significant units or IBAs as recognized by the National Audubon Society. Though the presence of habitats that are critical for the breeding, foraging, or migration of species with notable conservation status may not currently include federally listed species, their ecological importance for these significant species groups necessitates careful management to avoid potential degradation. Low Concern areas were not strictly demarcated due to the lack of comprehensive inventories and mappings of Special Status Species.

2.1.3. EDCI Mining Composite Index

The EDCI Mining Composite Index is a quantitative measure designed to evaluate and aggregate five economic capacity areas (financial, human capital, industry composition, infrastructure, institutions and partnerships) of the EDCI. Human capital measures the overall composition of the workforce and the quality of life for all residents in a county that could impact a mining project, with higher values indicating better human capital. Financial capital measures the financial environment within a county, including the accessibility of public sector capital funds to the private sector and the relative health of local government finances that could impact a mining project, with higher values indicating stronger financial support. Industry composition measures the business environment within a county, including the presence of local employment and establishment clusters, industry diversity, business entrance and exit rates, and the presence of industries that could impact a mining project. Lower original values correspond to higher scaled values, and vice versa. Less concentration (more diversity) of industry could be more favorable in a mining project. Infrastructure measures the physical and environmental resources that make economic development activities possible and support quality of life, including transportation, ports, energy reliability, broadband, land or water quality, and amenities that could impact a mining project. Higher values indicate more robust infrastructure. Institutions and partnerships measure the public and private entities that support and facilitate economic development, entrepreneurship, and innovation through collaborative networks that could impact a mining project, with higher values indicating stronger institutional support and more opportunity for possible partnerships.

More information about the EDCI Mining Composite Index can be found in Appendix 1.

2.1.4. CEJST Concern Level

The Climate and Economic Justice Screening Tool (CEJST) is an interactive mapping tool used by federal agencies to identify disadvantaged communities that are marginalized by underinvestment and overburdened by pollution. CEJST features a user-friendly, searchable map that identifies disadvantaged communities across all 50 states, the District of Columbia, and the U.S. territories using a variety of indicators. Land within the boundaries of Federally Recognized Tribes, including Alaska Native Villages, are highlighted as disadvantaged on the map. Data is updated on an annual basis. For most indicators, national percentiles are used to compare communities – any community above the 90th percentile for a particular indicator and above the 65th percentile for low-income is considered a Justice40 community. However, a few indicators, such as presence of abandoned mine land or formerly used defense sites, are binary – yes (1) or no (0). In these cases, any communities with a '1' score that are also above the 65th percentile for low income are considered disadvantaged. Further details on all of the indicators used in CEJST can be found at https://screeningtool.geoplatform.gov/en/#7.73/24.114/-104.579.

2.2. Critical Minerals Web Map Application

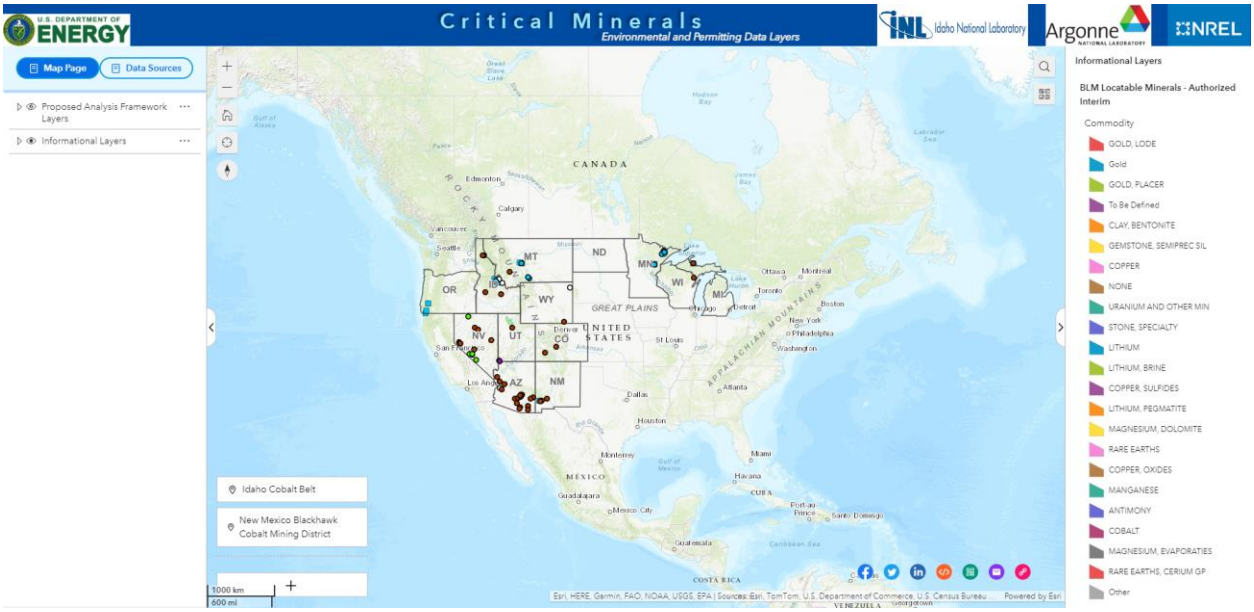

Figure 2. Critical mineral web map application.

The web map application, depicted in Figure 2, serves as the visual interface for this analytical journey. It allows users to interact with and layer the various spatial data sets, resulting in a dynamic and informative experience. Through this tool, stakeholders can visualize the spatial distribution of critical minerals, overlaid with detailed environmental, regulatory, and socio-economic data, thus gaining a holistic view of the potential impacts and viability of mineral development projects.

The Suggested Analysis Framework, along with the web map application, aims to provide a clear, actionable, and informed pathway for stakeholders to identify and prioritize areas for critical mineral exploration and extraction. This initiative supports the DOE's strategic objectives to fortify national supply chains and underpins the broader goal of advancing the nation's energy independence and economic fortitude through responsible resource stewardship.

In the ensuing sections, this report will delve into the specifics of the framework (Table 2), offering insights into the rationale behind each level of concern and providing guidance on how to leverage the web map application to its fullest potential. This framework will be illustrated through one case study: the ICB. Users will find this resource invaluable for understanding the challenges, opportunities, and potential for mineral extraction, and it will serve as a guide for analyzing other minerals or regions in a similar manner. Through this framework, users will find a valuable resource for making sense of the multifaceted landscape of critical mineral development in the United States.

Table 2. Proposed analysis framework table that categorizes levels of concern for land, species, economic, and environmental justice spatial feature.

INITIAL ASSESSMENT OF LIKELY CONCERN LEVEL			
LEVEL OF CONCERN	**HIGH CONCERN**	**MID CONCERN**	**LOW CONCERN**
Withdrawn & Potential Conflict Withdrawn Lands	**Definition:** Lands explicitly withdrawn from locatable mineral entry to preserve significant environmental, cultural, or ecological values. **Justification:** Classified as High Concern, these lands are protected under specific legal or administrative orders to prevent any locatable mineral activities that could adversely affect their critical values. The high rating reflects the substantial potential impact that violating these protections would have on the designated conservation priorities.	**Definition:** Lands withdrawn for specific non-mining purposes that might conflict with mineral development. **Justification:** These areas receive a Mid Concern rating because the designated purpose of the land withdrawal (e.g., conservation, recreation, cultural preservation) could potentially be compromised by mining operations. The likelihood and extent of conflict are contingent upon the specific restrictions associated with the withdrawal.	**Definition:** Lands not subject to withdrawal from locatable mineral entry. **Justification:** These areas are classified as Low Concern due to the absence of statutory or regulatory restrictions that prohibit mineral exploration and extraction, implying minimal conflict between mining activities and current land use. Given this, identifying Low Concern lands as a separate polygon layer is unnecessary since it encompasses all areas not categorized as High or Mid Concern.
Special Status Species	**Definition:** Presence of designated critical habitats for species that are listed under federal law, or proposed for listing, within the area of concern (See Limitations of the Web Map Application). **Justification:** Classified as High Concern due to the existence of legally	**Definition:** Presence of Greater sage grouse biologically significant units or Important Bird Areas (IBAs) as recognized by the National Audubon Society with the area of concern (See Limitations of the Web Map Application).	**Definition:** Areas (See Limitations of the Web Map Application) not currently identified as critical habitats for federally listed species, Greater sage grouse biologically significant units, or IBAs.

INITIAL ASSESSMENT OF LIKELY CONCERN LEVEL			
LEVEL OF CONCERN	**HIGH CONCERN**	**MID CONCERN**	**LOW CONCERN**
	protected habitats critical for the survival and recovery of endangered, threatened, or proposed species. These areas are subject to regulatory protections aimed at preserving biological diversity and ecological health, indicating a high priority for conservation efforts and stringent regulatory compliance to mitigate impacts on these habitats.	**Justification:** This level is designated due to the presence of habitats that are critical for the breeding, foraging, or migration of species with notable conservation status. Although these areas may not be currently include federally listed species, their ecological importance for these significant species groups necessitates careful management to avoid potential degradation.	**Justification:** These areas are classified as Low Concern due to the lack of identified critical habitats or significant conservation status species. However, delineating these areas as a separate polygon layer is unnecessary, as they encompass all regions not classified as High or Mid Concern. Additionally, the potential presence of undiscovered special status species suggests that blanket identification could be misleading or incomplete. Therefore, these areas should be monitored for any future discoveries that could impact their conservation status.
Economic Development Capacity Mining Index	**Definition:** Counties with low scores (0 to 0.31) suggest low economic capacity across the five capacity areas in the context of a mining project. **Justification:** Scores within this range could indicate underdeveloped economic conditions and challenges in the	**Definition:** Counties with mid range scores (0.32 to 0.5) suggest moderate economic capacity across the five capacity areas in the context of a mining project. **Justification:** Scores within this range could indicate a mix of developed economic	**Definition:** Counties with high scores (0.51 to 0.92) suggest high economic capacity across the five capacity areas in the context of a mining project. **Justification:** Scores within this range could indicate

INITIAL ASSESSMENT OF LIKELY CONCERN LEVEL			
LEVEL OF CONCERN	**HIGH CONCERN**	**MID CONCERN**	**LOW CONCERN**
	context of a mining project.	conditions for some capacity areas and underdeveloped conditions for other capacity areas.	developed economic conditions and less challenges in the context of a mining project.
CEJST Concern Level	**Definition:** The area of interest has one or more census tracts marked high concern for one or more CEJST indicators. A census tract is designated as high concern if: a) At least one of the census tracts immediately surrounding the area of interest are above the 90th percentile for at least one indicator; AND/OR b) For binary (yes-no) indicators such as abandoned mine land, at least one of the census tracts immediately surrounding the area of interest have a '1' value (yes) for at least one indicator. **Justification:** Assigned due to the significant presence of socio-economic, climate, and environmental challenges faced by these communities. Such areas are primary targets for investments aimed at addressing disparities in climate	**Definition:** The area of interest has no census tracts marked high concern for any indicators, but does have one or more census tracts marked medium concern for one or more indicators. A census tract is designated as medium concern if: a) At least one of the census tracts immediately surrounding the area of interest are above the 50th percentile for at least one indicator. **Justification:** This classification indicates a mixed scenario where certain segments of the population or specific geographic areas within the larger area of interest exhibit characteristics of socio-economic and environmental vulnerability. These communities might benefit from targeted interventions, but the overall level of need and potential impact of federal investments may vary.	**Definition:** The area of interest has no census tracts marked high concern or medium concern. A census tract is designated as low concern if it is: a) Below the 50th percentile for all percentile-based indicators, AND c) Without any '1' values for binary (yes-no) indicators, such as abandoned mine land. **Justification:** This rating suggests that the area predominately consists of communities that do not meet the criteria for disadvantage as defined by federal guidelines. These areas are likely to have better access to resources and fewer environmental or health burdens.

INITIAL ASSESSMENT OF LIKELY CONCERN LEVEL			
LEVEL OF CONCERN	**HIGH CONCERN**	**MID CONCERN**	**LOW CONCERN**
	change impacts, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. Federally Recognized Tribes are also considered disadvantaged communities. The designation represents the urgent need to concerted efforts to channel benefits and resources effectively to these communities.		

2.2.1. Limitations of the Web Map Application

It is important to recognize that the web map application is not intended to be a definitive tool for conducting comprehensive environmental or social analyses, nor can it reflect the full scope or depth of stakeholder perspectives and concerns. While the GIS layers provide known or inventoried delineations, each layer comes with inherent limitations and potential errors. As the application demarcates areas with set boundaries, it does not offer a detailed environmental analysis of how a given mining project may impact surrounding areas.

For instance, critical habitats for species listed under the Endangered Species Act (ESA) might be affected by a mining project even if these habitats are not present at the exact location of the development. Activities associated with mining, such as surface water contamination, dust dispersion, noise pollution, introduction of invasive species, etc. can have off-site impacts on listed species.

Similarly, areas designated as Withdrawn Lands or Potential Conflict Withdrawn Lands require careful consideration of how nearby actions might affect their viewshed or the purpose for their withdrawal. Land managers must take into account the potential impacts of adjacent activities on these withdrawn lands, as strict demarcations of spatial boundaries cannot fully capture the potential indirect effects of nearby actions.

Additionally, American Indian land delineations in the application do not fully represent all Indian land claims or land sensitivities for federally recognized tribes. The web map does not capture the full scope of cultural, historical, and spiritual significance that these lands hold for American Indian communities. Therefore, any planning or permitting processes should engage with Tribal entities to ensure that these considerations are comprehensively addressed.

Therefore, the tool should be viewed as a preliminary, high-level tool for assessing initial concern levels, rather than a substitute for detailed analyses, stakeholder engagement, or environmental reviews required under the National Environmental Policy Act (NEPA) and other laws that may be applicable,

such as the National Historic Preservation Act. Users must conduct further, more detailed analyses to fully understand the environmental and social implications of proposed mining projects.

2.3. Informational Layers

The web map application integrates a variety of geospatial data layers tailored towards supporting critical mineral development. These layers include Economic Development Capacity Indices (EDCI), which provide essential insights into the economic potential and infrastructure readiness of various regions, and the FEMA Community Resilience Challenges Index, which helps identify areas that may require additional support to withstand and recover from disruptions. Climate Justice and Economic Screening Tool layers ensure that environmental and socio-economic factors are considered, promoting equitable development.

Critical mineral data from USGS and INL offer detailed information on mineral deposits, aiding in resource exploration and management. The BLM Locatable Minerals - Authorized Interim geospatially represents case groups for the Mineral and Land Records System (MLRS). Layers such as USA States, Region of Interest, USA Counties, and BLM Surface Management Administration facilitate spatial analysis and jurisdictional awareness. Wildlife Migration Corridors and Land Cover layers are critical for assessing environmental impacts and planning sustainable development practices. Additionally, the Social Value of Ecosystem Services (SolVES) tool data provide insights into the societal benefits derived from ecosystems (Sherrouse 2022), while Right of Way data and Grazing Administration data are essential for managing land access and existing uses.

Together, these data layers offer comprehensive, actionable insights, empowering users to make informed decisions in critical mineral development while considering economic, environmental, and social factors.

3. RESULTS/ANALYSIS

3.1. Idaho Cobalt Belt Case Study

To illustrate the practical utility of this tool, the proposed analysis framework of the Web Map Application was utilized to conduct a case study of the Idaho Cobalt Belt (ICB). The ICB is a northwest-trending belt of cobalt (Co) and copper (Cu) bearing deposits and prospects, located in the Salmon River Mountains of east-central Idaho (Bookstrom 2013). This belt spans approximately 55 km in length and 10 km in width at its central part, which encompasses multiple strata-bound ore zones in the Blackbird mine area. Key prospects include the Black Pine and Iron Creek Co-Cu prospects situated southeast of Blackbird, and the Tinkers Pride, Bonanza Copper, Elk Creek, and Salmon Canyon Copper prospects located northwest of Blackbird (Bookstrom 2013). The following sections detail the results derived from employing the tool in the ICB case study.

Each data layer provided under the outlined subgroupings of the Proposed Analysis Framework is discussed individually.

3.1.1. Argonne's EDCI Mining Composite Index

The ICB is located within Lemhi County, Idaho. The EDCI Mining Composite Index shows that Lemhi County falls into the Mid-Concern category with a score of 0.41, a rank of 1,687 out of 3,213 counties, and is in the 52.5th percentile (Figure 3). This score suggests that the county has moderate economic capacity in the five capacity areas in the context of a mining project. The rank indicates that the county is positioned slightly above the median among all 3,213 counties evaluated, providing a relative perspective on how the county stands compared to other counties in the United States.

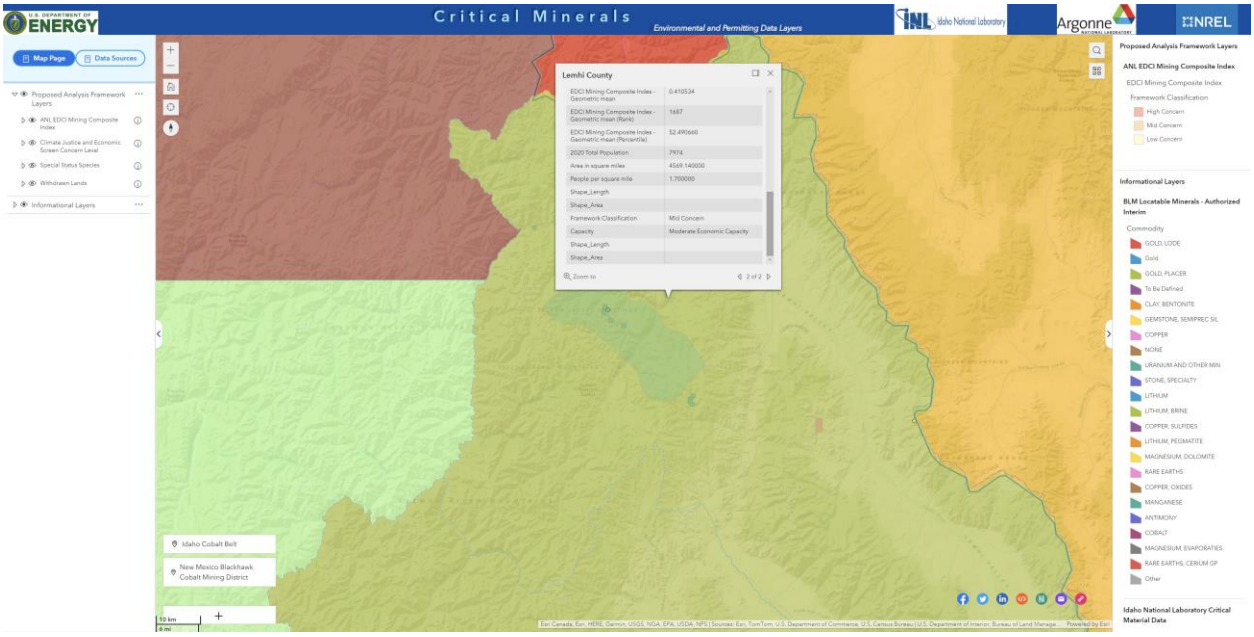

Figure 3. This map shows the ANL EDCI Mining Composite Index for the ICB in Lemhi County, Idaho. Lemhi County is categorized as Mid-Concern with a score of 0.41, ranking 1,687 out of 3,213 counties (52.5th percentile).

Contributing factors that could influence Lemhi County's score include its low level of human capital (14th percentile), about average levels of physical resources and environmental considerations (50th percentile), and a relatively strong industry capacity (64th percentile) when compared to the national average.

Lemhi County's financial capacity is somewhat limited (45th percentile), but in the context of a mining project, that would not be a driver of the index score as projects often bring their own capital. Additionally, though its institutions and partnership capacity are considered elevated (87th percentile), this capacity area was not weighted as heavily as others.

3.1.2. Climate Justice and Economic Screening Tool (CEJST) Concern Level

The ICB falls in the High Concern category for CEJST indicators. Rates of heart disease in two of three Lemhi County census tracts are above the 90th percentile relative to the rest of the country (Figure 4). Rates of asthma are above the 50th percentile in two of three Lemhi County census tracts. Both heart disease and asthma may be exacerbated by mining-related impacts, such as dust and particulate pollution, if unmitigated (AirNow).

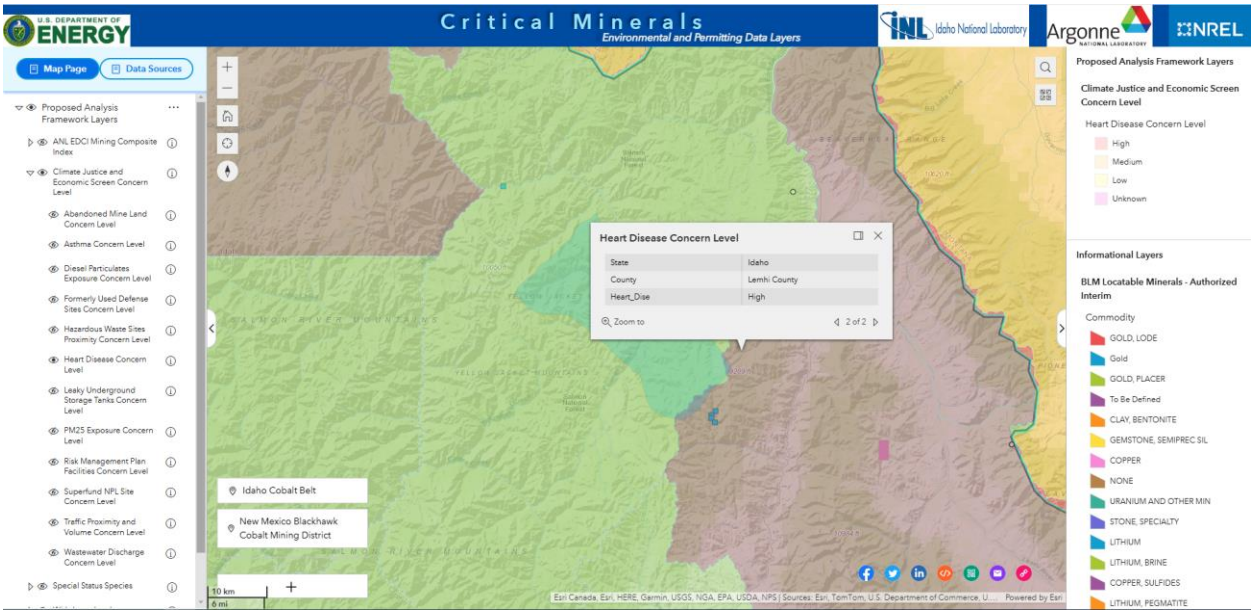

Figure 4. This map shows the CEJST Heart Disease Concern Level for the ICB. Two of Lemhi County's three census tracts are categorized as High Concern.

The ICB in Lemhi County is in the Low Concern category for all other CEJST indicators.

3.1.3. Special Status Species

The ICB area provides critical habitat for bull trout (*Salvelinus confluentus*) and steelhead (*Oncorhynchus mykiss*), both of which are listed as Threatened species (Figure 5)(NOAA Fisheries' West Coast Region ; U.S. Fish & Wildlife Service). Bull trout require cold, clean, complex, and connected habitats (Gutowsky et al. 2017), making their preservation a high concern in any planning or permitting processes. Similarly, effective steelhead recovery necessitates coordinated action across all levels of government and stakeholders (Center 2017). Partnerships among federal, state, local, and Tribal entities, along with non-governmental and private organizations, are crucial for restoring healthy salmon and steelhead populations and ensuring the associated cultural, economic, and environmental benefits. Therefore, it is essential to prioritize the conservation of these species in all relevant activities.

By utilizing GIS datasets that delineate habitats and occurrences of special status species, planners can better understand the commitments necessary for siting or permitting in the ICB area. To streamline analysis and simplify decision-making, these habitat layers were consolidated and categorized into "Mid concern" and "High concern" levels, as depicted in Table 2.

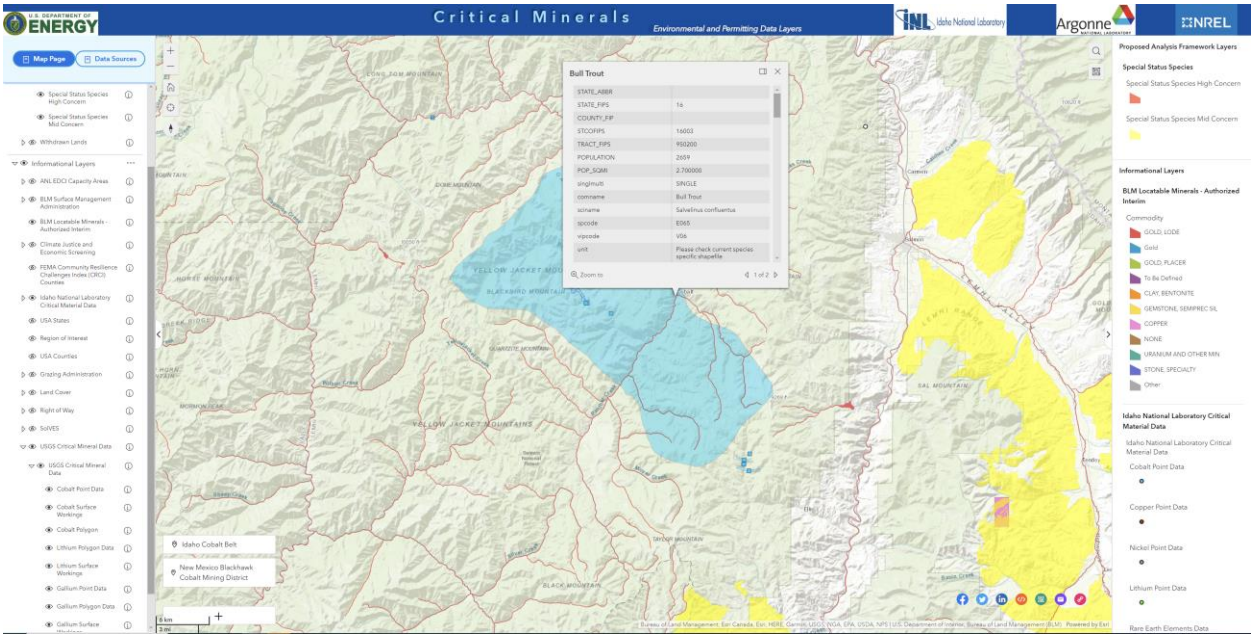

Figure 5. Web map application displaying a popup of bull trout critical habitat line feature (red, high concern) intersecting with the USGS Cobalt Polygon data within the Idaho Cobalt Belt (ICB) area. The USGS Cobalt polygon and points (square), along with the INL Cobalt points (circular), are all colored baby blue. The yellow polygon features to the east represent Mid concern areas for special status species, specifically Idaho Mountain Conservation areas (Burger et al. 2020).

The web map application tool reveals that bull trout and Snake River basin steelhead habitats intersect with the USGS Cobalt Polygon, and Cobalt Points are in close proximity. This spatial relationship identifies a need for heightened awareness and careful consideration during development activities. Bull trout face numerous threats, including habitat degradation from land use and development, barriers to migration such as dams or weirs, and competition or predation from non-native species(U.S. Fish & Wildlife Service). These factors collectively impact their survival and population recovery.

Given these considerations, the ICB area's role as a habitat for bull trout should be prioritized, ensuring that any planning and development efforts minimize adverse impacts on this vulnerable species.

3.1.4. Withdrawn & Potential Conflict Withdrawn Lands

The Withdrawn Lands dataset is a comprehensive compilation of various land parcels across the United States that have been withdrawn from mineral entry. This dataset is crucial for conducting analyses related to critical mineral resources and supports decision-making and policy development concerning land management and conservation, as detailed in Table 2.

Within the ICB area, two types of withdrawn lands intersect the USGS Cobalt Polygon (Blackbird District) and associated cobalt point data (Figure 6). The first is a High Concern area, specifically the Frank Church-River of No Return Wilderness, which covers a portion of the west side of the USGS Cobalt Polygon. Lands designated as High Concern are explicitly withdrawn from locatable mineral entry to preserve significant environmental, cultural, or ecological values. These areas are protected under specific legal or administrative orders to prevent any mineral activities that could adversely affect their critical values. The high rating reflects the substantial potential impact that violating these protections would have on the designated conservation priorities.

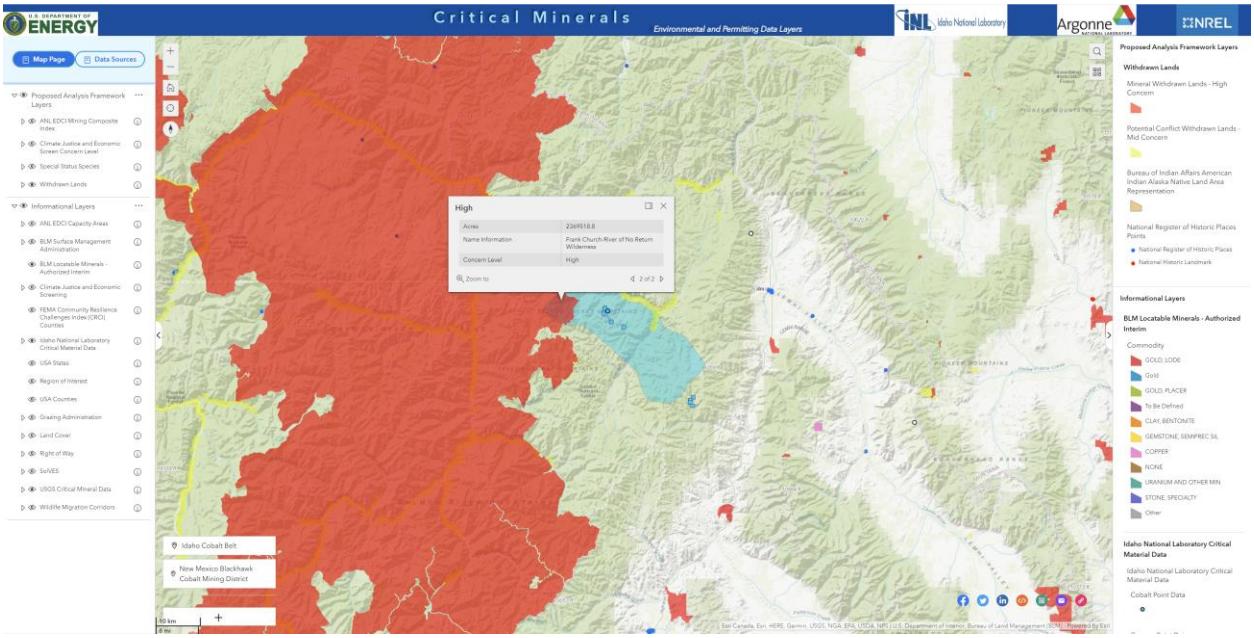

Figure 6. Web map application displaying a popup of the High Concern area (reddish orange), specifically the Frank Church-River of No Return Wilderness. The yellow polygons delineate Mid Concern areas. Within the Idaho Cobalt Belt (ICB) area, point location information for the Idaho Cobalt Project, East Sunshine, and Blackbird mineral occurrences is also included, which are baby blue square and circular points. These points highlight the presence of mineral commodities such as cobalt, gold, copper, silver, and iron. This comprehensive information is integrated into the web map application.

The second type is a Mid Concern area, identified as Powersite Classification No. 280, which is located to the north of the USGS Cobalt Polygon. Lands withdrawn for specific non-mining purposes, such as conservation, recreation, or cultural preservation, receive a Mid Concern rating. These areas could potentially conflict with mineral development, and the likelihood and extent of this conflict depend on the specific restrictions associated with the withdrawal.

Additionally, there is a USGS Cobalt Point situated on the Power Withdrawal Powersite Classification 50 at the Salmon Canyon mineral occurrence site, which is known for copper, cobalt, gold, and silver deposits. This highlights the need for careful consideration and analysis to balance mineral development with the preservation of these withdrawn lands.

The web map application visually represents these intersections, providing a clear understanding of the spatial relationships and potential conflicts between critical mineral resource areas and withdrawn lands, facilitating informed decision-making and policy development.

Web map application displaying a popup of bull trout critical habitat line feature (red, high concern) intersecting with the USGS Cobalt Polygon data within the Idaho Cobalt Belt (ICB) area. The USGS Cobalt polygon and points (square), along with the INL Cobalt points (circular), are all colored baby blue. The yellow polygon features to the east represent Mid concern areas for special status species, specifically Idaho Mountain Conservation areas.

3.2. Applying Analysis Framework to Cobalt Reserve Sites

The analysis framework is applied to identified Cobalt deposits across a 13-state region, to demonstrate how it can be used to assist with site selection, land use prioritization, and critical mineral supply analysis. This framework demonstrates how not all deposits are created equal and analyses that

simply add all US deposits together do not necessarily consider the challenges with actually realizing the potential of those deposits.

Using this analysis framework to consider all cobalt deposits in the 13-state region also reveals its shortcomings. For instance, most deposits are not on any withdrawn lands, despite several being located in national forests or parks. These deposits may have higher community concerns or longer permitting timelines depending on the local context. It is important to note that this analysis framework is not intended to serve as regulatory guidance or as land use prioritization, but merely inform future analysis. The presence of special status species for instances, which may make a site high concern, does not necessarily preclude a site from development, but merely indicates the need to consider impact mitigation if that site is developed.

Figure 7. Applying analysis framework to identified cobalt deposits in the 13-state region.

4. KEY CONSIDERATIONS

Like any tool, it is important to keep in mind the intended purpose and use, when applying it to problems. The GIS application and the analysis framework are intended to provide high-level data analysis relevant to a variety of stakeholders. However, the data presented here is not necessarily comprehensive, nor does the data necessarily reflect the on the ground reality of various stakeholder claims. Finally, the analysis framework is not intended to present any guidance for siting, permitting, or other regulatory proceedings. But the data presented here can be a useful tool for a variety of stakeholders.

For developers, this tool can help provide an accessible, high-level tool to quickly learn various socioeconomic and environmental data points regarding a given site, to better understand meaningful engagement channels and sensitivities. This tool is intended to collect data to inform developers engagement and permitting processes and is not intended to substitute community involvement or provide guidance on regulatory processes.

For state and federal agencies, this tool can assist environmental permitting reviewers to point to areas for further study or complementary data resources relevant for analysis. The open-source GIS layers can also be utilized to support informed land use planning and identifying critical mineral sites that may be more amenable to development and support regional or national land use coordination and prioritization.

For supply chain analysts, our analysis framework and GIS application can help provide high-level assessments of the feasibility of different critical mineral deposits, and inform policymaking based on reasonable subset of sites, rather than simplistic aggregation of all assessed deposits. The GIS application can also act as a data repository for assessing opportunities for place-based critical mineral hubs and potential socioeconomic benefits or impacts from critical mineral development.

5. CONCLUSIONS

Understanding critical minerals and the complex considerations for their development is paramount for developing secure energy supply chains. In this report, we present a new GIS application for critical mineral reserves that collates over 120 public GIS layers relevant to siting and permitting critical mineral sites, ranging from land use, to socioeconomic indicators, to endangered species. To our knowledge, this is the most comprehensive GIS data repository of information relevant to critical minerals and is designed to be a tool that is useful to developers, state and federal agencies, and future analysis for understanding the US's critical mineral potential. We also introduce a high-level analysis framework to aggregate GIS layers to analyze potential site viability. This GIS application and analysis framework are meant to support policymakers, researchers, land-use planners, and environmental reviewers but in no way supplants the need for robust community engagement for critical mineral projects.

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Appendix A

Economic Factors Influencing Mining Project Siting and Permitting

EDCI Capacity Area	EDCI Definition	Mining Context	Weight
Financial	The financial environment within a county, including the accessibility of public sector capital funds to the private sector and the relative health of local government finances.	Financial capacity in a mining project could be considered a net neutral: High financial capacity, such as support from local government and private sector infusions, as well as the availability of diverse funding sources could positively impact a mining project. Low financial capacity in an area may not impact a mining project in a negative way, as many projects bring their own capital.	1
Human Capital	The overall composition of the workforce and the quality of life for all residents in a county.	Human capital in a mining project could contribute to economic growth: High human capital and quality of life, or a diverse composition of the workforce could benefit a mining project. Avoiding the need to recruit and source talent clears financial and timeline hurdles while boosting economic activity within an area's local workforce. A highly educated and trained workforce facilitates increased industry diversity within a community. Additionally, increased levels of prosperity and quality of	2

EDCI Capacity Area	EDCI Definition	Mining Context	Weight
		life could aid in attracting individuals to an area. Low human capital and low quality of life in an area may negatively impact a mining project, which relies on a skilled workforce and at times, has difficulty recruiting specialized talent for a project.	
Industry	The business environment within a county, including the presence of local employment and establishment clusters, industry diversity, business entrance and exit rates, and the presence of industries.	Industry capacity in a mining project could contribute to economic growth: High industry capacity and industrial clusters that generate a lot of employment for local communities may signal less interest or need of mining operations. Low industry capacity may signal an opportunity for a mining project, to boost diversification, local economic activities, and employment.	*2*
Infrastructure	The physical and environmental resources that make economic development activities possible and support quality of life, including transportation, ports, energy reliability, broadband, land or water quality, and amenities.	Infrastructure capacity in a mining project could present both positive and negative factors: High infrastructure capacity could decrease operational costs and contribute to reliable supply chains. A robust and well-functioning transportation infrastructure could facilitate the transportation of mined materials, boosting efficiency and supporting the local economy. Reliable energy systems and broadband access	2

EDCI Capacity Area	EDCI Definition	Mining Context	Weight
		could also support operations, enhancing communication. Low infrastructure capacity could increase operational costs and disrupt supply chains. Environmental and power disruptions also pose risks to a mining operation. Mining could degrade land, water, and air quality, potentially harming local communities and industries dependent on these resources. Moreover, rural areas, where mining often takes place, may face limited broadband access and infrastructure issues, complicating logistics and operations.	
Institutions/ Partnerships		Institutions & Partnerships in a mining project could impact the project in the following ways: High institutions and partnerships capacity may indicate that the area is in an Economic Development District, which could assist in connecting projects to resources and fosters collaboration among local stakeholders. Low institutions and partnerships capacity may offer an opportunity for a mining project to bring new areas of economic development and resources to an area.	1