UNM METALS Superfund Research Center

Metal Exposure and Toxicity Assessment on tribal Lands in the Southwest

Uranium Waste Spills – Acute and Chronic Effects Over 80 years

Session 3: Disaster Response Research

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NIEHS Superfund Research Program Annual Grantees Meeting, Albuquerque, NM
December 4, 2023
Revised April 18, 2024 for NAU SUS 220 (Dr. Tommy Rock)

COLLEGE OF PHARMACY
METAL EXPOSURE AND TOXICITY ASSESSMENT ON TRIBAL LANDS IN THE SOUTHWEST
Superfund Research Program
SOUTHWEST RESEARCH AND INFORMATION CENTER
PUEBLO OF LAGUNA
INDIGENOUS EDUCATION INSTITUTE I.E.I

Acknowledgements

- **DiNEH Project Funding:** NIEHS R25ESO13208, RO1ES014565; in-kind support from Crownpoint PHS Hospital and Eastern Navajo Health Board
- **NBCS-ECHO+ Funding:** Cooperative Agreement between NIH (UG3OD023344) and UNM Community Environmental Health Program, in partnership with the Navajo Nation Department of Health, Southwest Research and Information Center, UNM Center for Development and Disability, and University of California, San Francisco
- **UNM METALS SRP:** NIH/NIEHS P42 ES025589 (UNM METALS); NSF Award #1652619 (Cerrato CAREERS)
- **Approvals:** Human research is approved and monitored by the UNM Human Research Protections Office and Navajo Nation Human Research Review Board: DiNEH Project, NNR-04-145; NBCS, NNR-11.323; NBCS-ECHO+, NNR-19.360; Thinking Zinc, NNR-18.330T.

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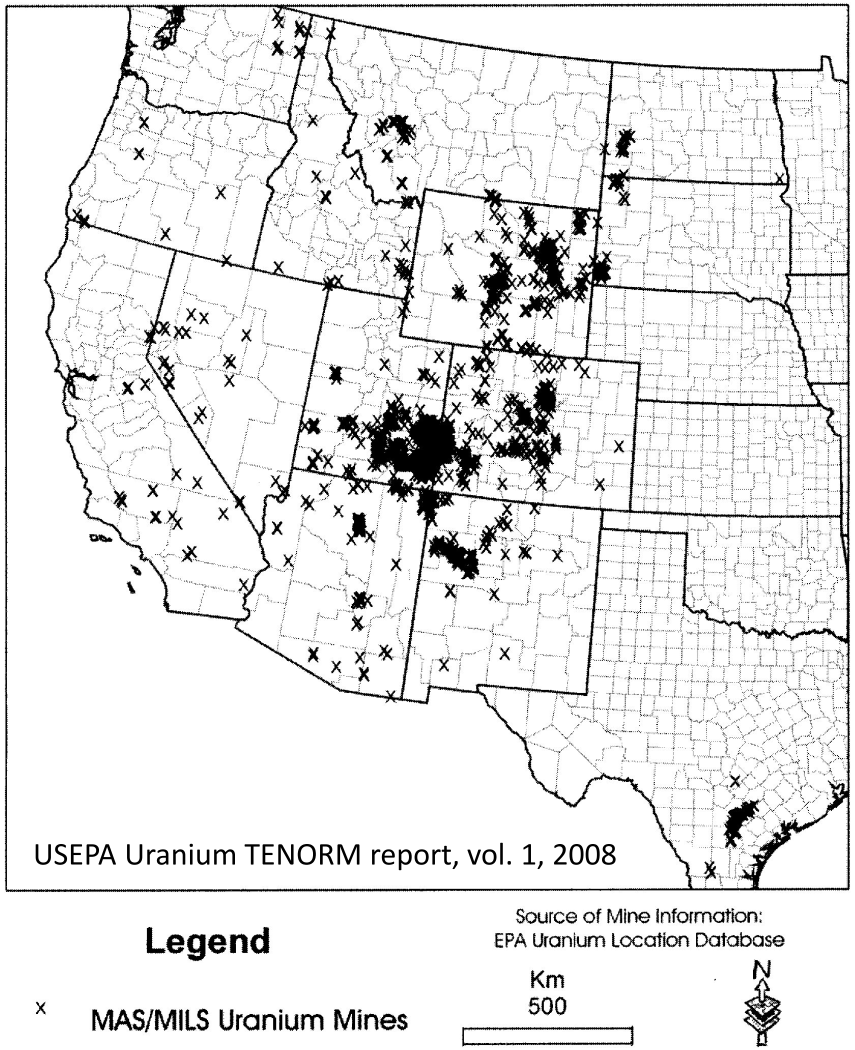
Communities: We recognize and honor the communities and community organizations that are partners in the UNM METALS Superfund Research Center:

- Blue Gap-Tachee Chapter
- Cameron Farm Enterprise
- Indigenous Education Institute
- Pueblo of Laguna
- Red Water Pond Road Community Association

Land Acknowledgement Statement: *The University of New Mexico sits on the traditional homelands of the Pueblo of Sandia. The original peoples of New Mexico have deep connections to the land and have made significant contributions to the broader community statewide. We honor the land itself and those who remain stewards of this land and acknowledge our committed relationship to Indigenous peoples.*

The Uranium Legacy – a technological disaster 80+ years in the making



USEPA Uranium TENORM report, vol. 1, 2008

- The field of disaster research study has noted distinctions among natural disasters, technological accidents, and sudden episodes of mass violence (McFarlane et al., 2006).
- Since the first mining of uranium in Monument Valley AZ-UT in 1942, more than 10,000 uranium mines and more than 50 uranium mills were operated in 15 Western states, leaving hundreds of millions of tons of toxic and radioactive wastes
- While the “Uranium Legacy” has received attention under the federal Superfund Law, it has not been seen as a technological disaster with long-term environmental impacts and ongoing exposures to local populations

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Nomenclature: Uranium Mining v. Uranium Milling


1972 – Kerr-McGee/Quivira Churchrock Mine


2023– Quivira Churchrock Mine waste dump

Mine Wastes
- Low-grade ore, waste rock, overburden
- Left at open-pit and underground mines
- Not regulated by Federal Government since 1960

Mill Tailings
- Wastes from processing of uranium ore to produce uranium concentrate, called “yellowcake”
- Processing involves application of extreme acids or bases with addition of tertiary amines, solvents
- Only U removed; all other radiological and metal contaminants retained in tailings
- Federally regulated since 1978


1990 — Atlas Corp. uranium mill and tailings impoundment, Moab, UT


2023 — Crescent Junction (UT) Moab tailings disposal site

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Radiation Intensities of Various Nuclear Wastes Compared with Background

(A) Low, normal

(B) Elevated radiation, heavy metals

(C) High chemical toxcity, high radiation

(D) Dangerous radiation, remote-handled

(E) Deadly, remote handled

"Background," or natural conditions

Mine waste (Quivira CR1 Mine)

Uranium Mill Tailings (UNC, Churchrock)

Transuranic wastes (WIPP)

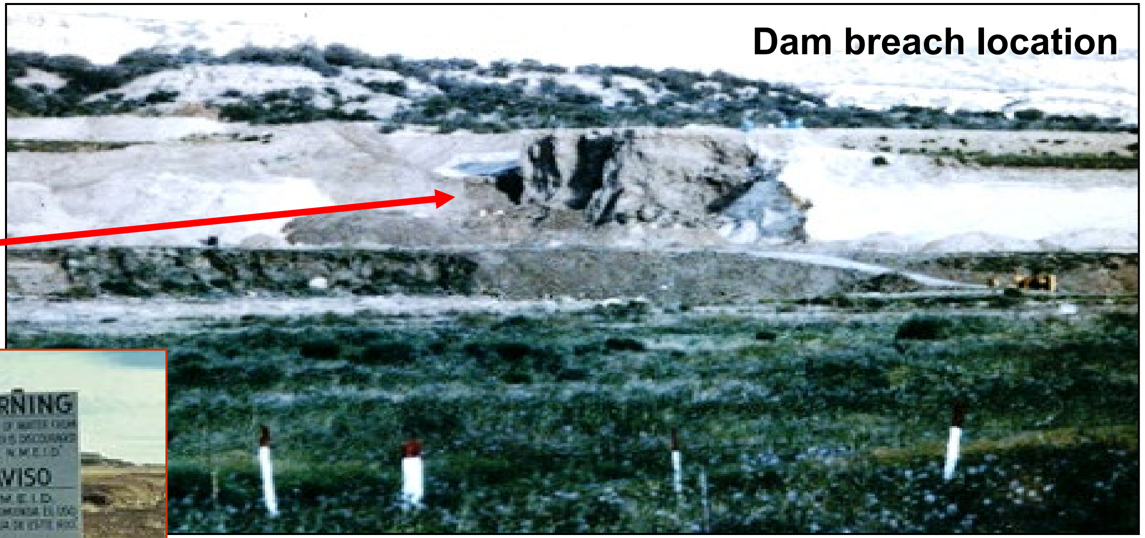
Spent nuclear fuel (Palo Verde NGS)

Church Rock Uranium Mill Tailings Spill July 16, 1979*

*Remains the largest release of radioactive wastes, by volume, in US history; third largest radiological disaster after Fukashima (2011) and Chernobyl (1986)

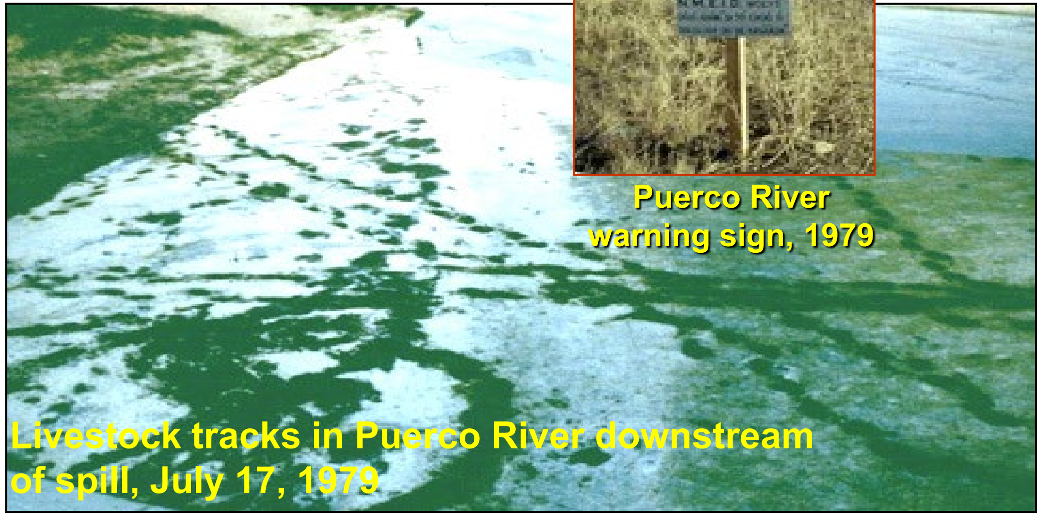

United Nuclear Corp. Uranium Mill Tailings Dam

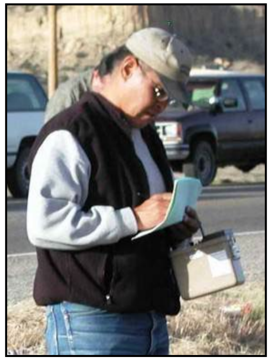
July 16, 1979


Dam breach location

Puerco River warning sign, 1979


NMEID sampling in Puerco River after spill


Livestock tracks in Puerco River downstream of spill, July 17, 1979



Community leaders Larry J. King and the late Robinson Kelly (right) emerged as community leaders in

Photo credits: KOAT-TV, Paul Robinson, Chris Shuey, public domain

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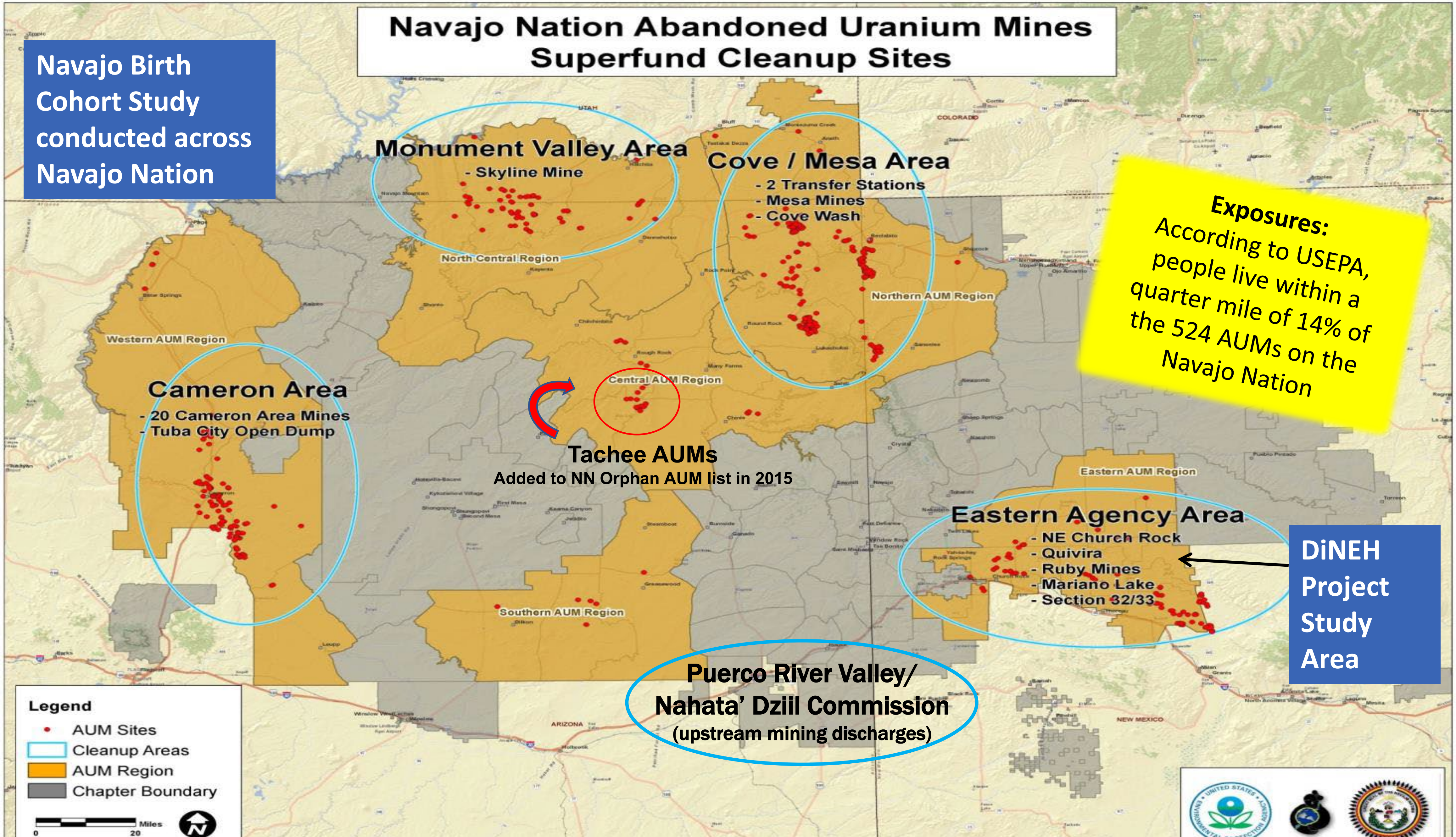
Characteristics of the Tailings Spill – Acutely toxic mill effluent*; Mine water – Chronic releases, greater volumes, more radioactivity

Event	Fluid Volume (gals)	pH	Metric Tons Uranium Released	U (mg/l) in fluids	Ra total (pCi/l) in fluids	Curies Gross Alpha Activity
Tailings Spill (1979)	94 million	***1.4-1.9**	1.5	**4.5-6.4**	**210**	46
Mine dewatering (1960-62, 77-86; combined 3 mines)	43.7 billion (ave. 5,200 gpm for 16 years)	7.66-8.82	560	**7.25** (‘75) 0.16-3.15 (’80-’83)	<1.0-**13.82**	**260**

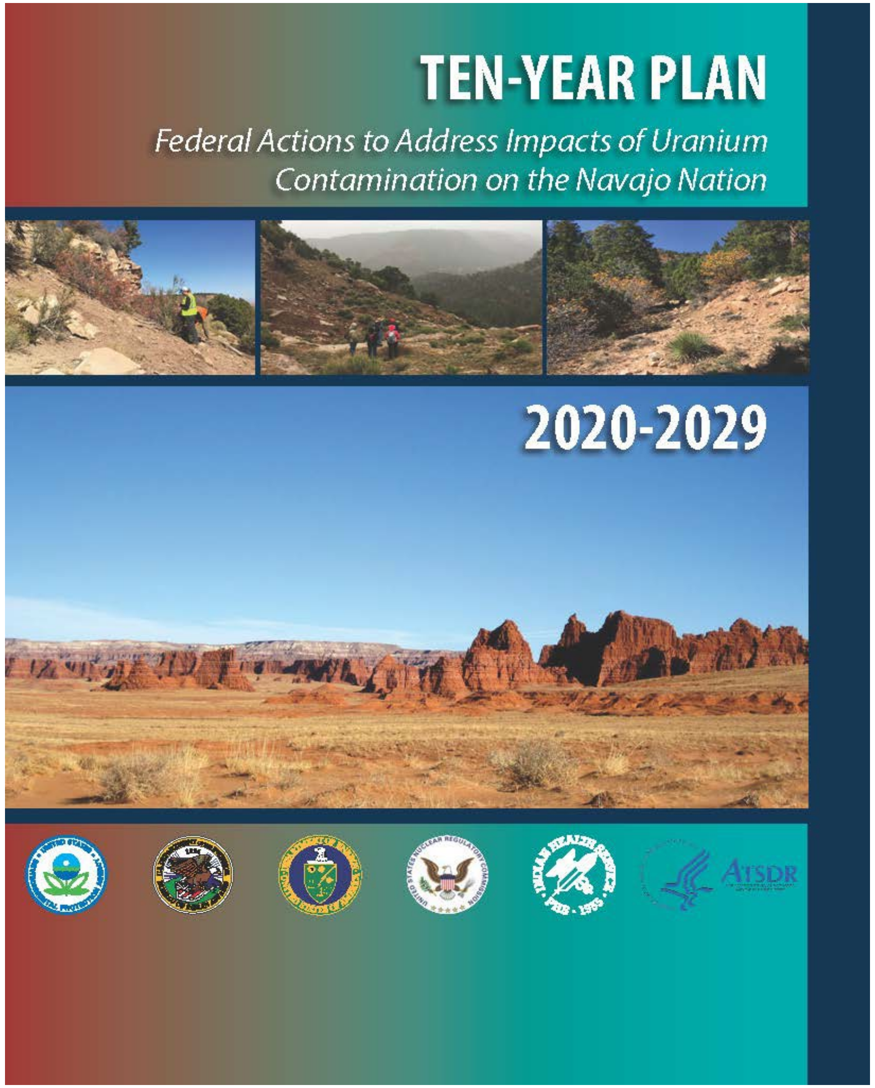
- NM Governor declined to make an emergency declaration after tailings spill
- Anecdotal reports from local residents: Numerous people, livestock sustained acid burns to feet and legs after wading into river in the hours and days after the spill
- No investigation of acute effects; whole-body radiation counting among a small group of local residents revealed no acute radiation effects
- Mine dewatering created a permanent flow in the usually ephemeral Puerco River between 1977 and 1986

Data sources: Goad et al., 1980; Shuey and Battista, App. II-B, 2007; USEPA, 1978; Van Metre et al., 1997.



Map courtesy USEPA Region 9, modified by SRIC

Navajo Uranium Legacy: By the Numbers



Cover of USEPA Ten-Year Plan, Jan. 2021

524	**Abandoned uranium mines (AUMs**
>1,100	Mine waste "features" – places were uranium ore and wastes were transported beyond the mine that generated them
0	***Fully remediated AUMs (from 10-Year Plan)***
4	Interim AUM remedial actions to contain wastes
96	AUM site radiation screening reports
130	Removal Site Evaluations (RSEs) expected to be completed by end of 2022
10-15	EE/CAs* expected to be completed by end of 2022
$1.7 billion	Money USEPA says it has available for remediating **~40% AUMs** through Tronox bankruptcy, settlements with mining companies, federal contributions
3	Congressional hearings: 1979, 1993, 2007
3	Federal response plans: 2008, 2014, 2021
57 (52%)	Navajo Chapters w/ 1-3 uranium exposure sources (AUMs, water sources, contaminated structures)

*EE/CA = Engineering Evaluation/Cost Analysis

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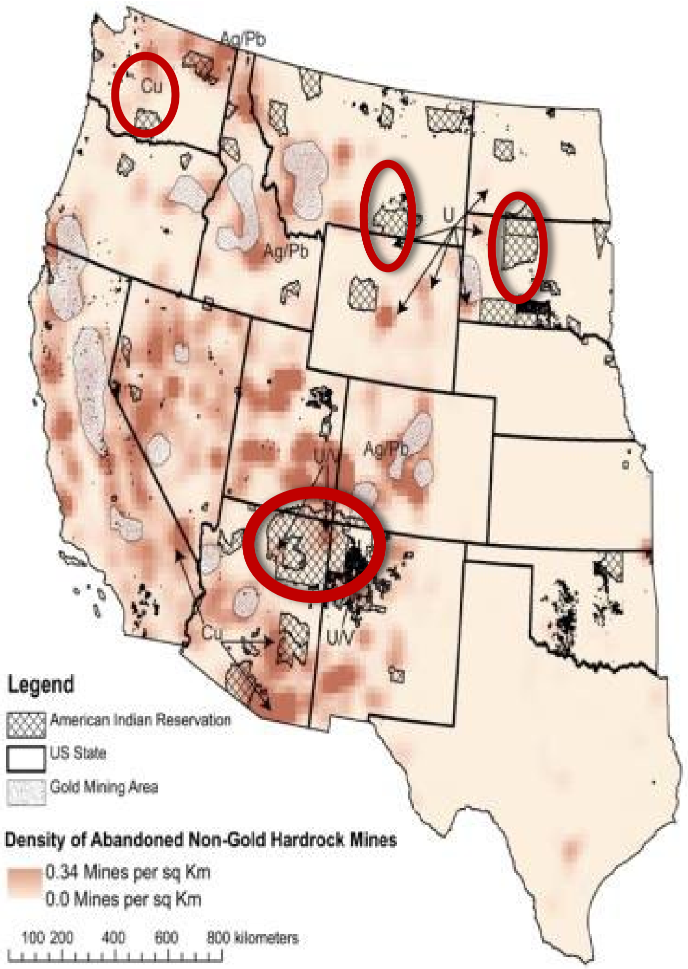
The Big Picture: Mining Impacts on Indigenous Americans

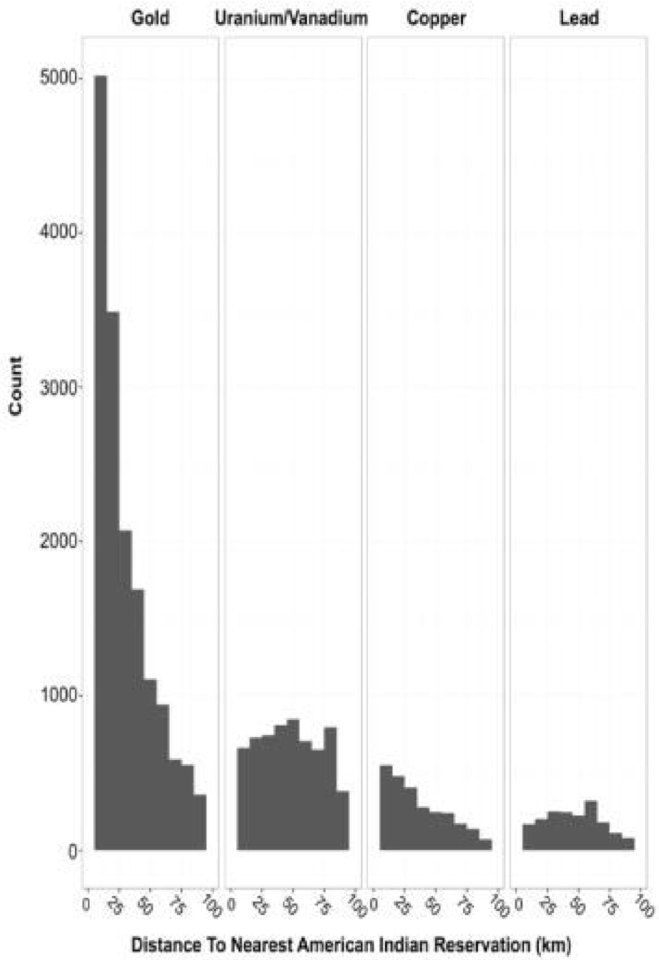
U.S. Western States

- 161,000 abandoned hard rock mines
- Uranium mines second only to gold mines
- >500,000 sites
- 40% of watershed headwaters in West thought to be contaminated from these mines (USEPA)
- >1/2 of US Indigenous population
- >600,000 Native Americans live within 10 km of abandoned mines

Potential for higher sensitivity to toxicity among Native Americans

- reliance on local resources
- understudied genetic, epigenetic metabolic, distribution differences
- Tied to land – relocation away from mine sites not always an option to reduce exposures





Lewis, Hoover, & MacKenzie (2017), Current Environmental Health Reports.

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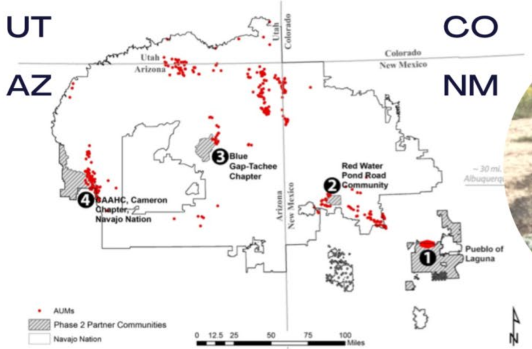
METALS's tribal communities face common, multi-generational risks from uranium mine wastes



1

Pueblo of Laguna

Affected population: ~1,800 (3 of 6 villages)
Jackpile-Paguate Mine ~2,700 acres, 8,500-acre lease
CERCLA National Priorities List, 2013
Production era: 1952-1982
Waste Volumes: 400 million tons
Interim Reclamation: 1989-1995
Hazardous substances: As, Cr, Co, Mn, U, V, Zn

2

Red Water Pond Road Community

Affected population: ~200 within 1.5 mi of 3 sites
CERCLA Sites: A. Northeast Church Rock Mine (removal), B.Quivira Mine (removal), C. Church Rock Uranium Mill Tailings (NPL 1983)
Production era: 1968-1983
Waste Volumes: ~3 million tons across 3 sites
Interim Reclamation: A. 2007-2012, B. 1991; 2006-2009 C. 1991-present.
Hazardous substances: As, Mo, NO3, Ra-226, Se, U, V

3

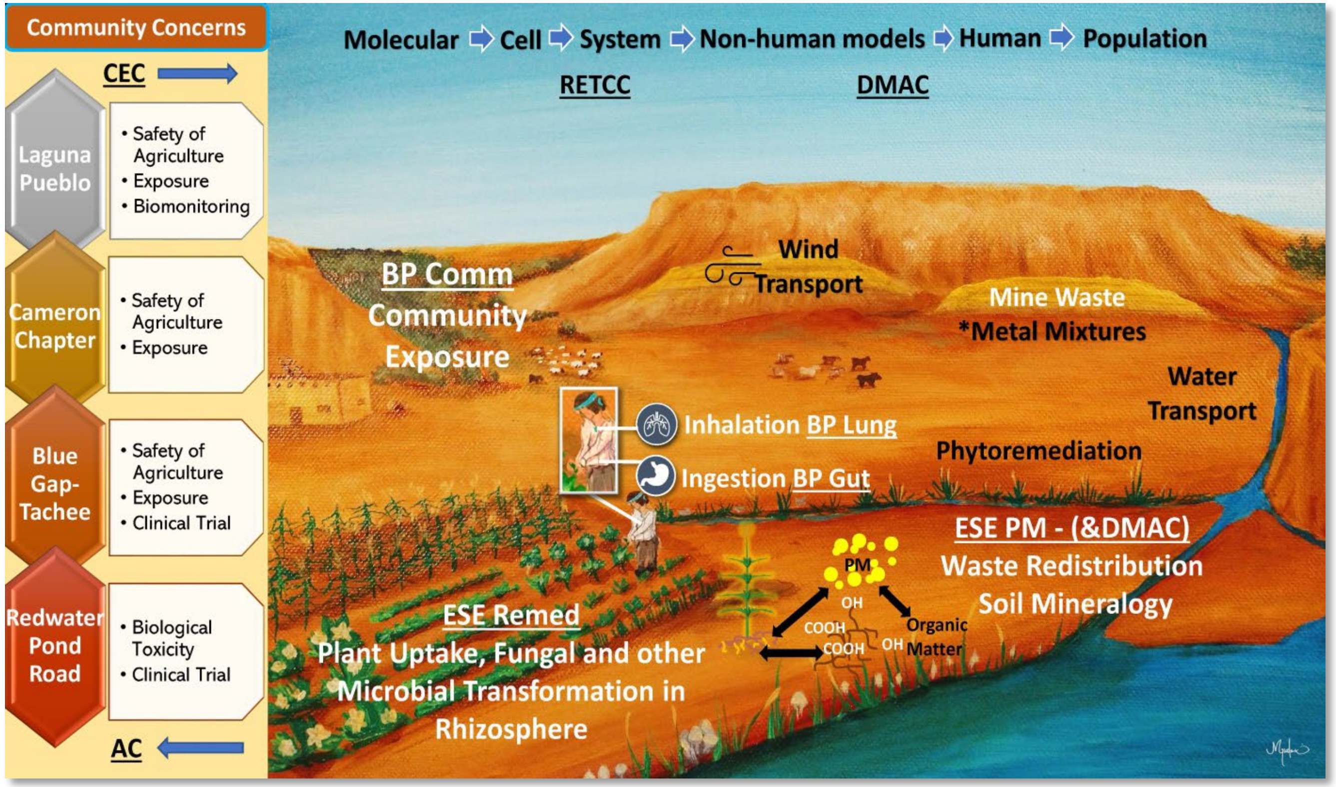
Blue Gap-Tachee Chapter, Navajo Nation

Affected population: ~17 families (~70 people)
CERCLA Sites: Claim 28 Mine +19 other AUMs
Production era: 1954-1968
Waste Volumes: 4,995 Cubic yards @ Claim 28; 17,000 tons U ore all mines
NNAML Reclamation to reduce safety hazards 1991-1992.
Hazardous substances: As, Fe, U, V

4

CAAHC, Cameron Chapter, Navajo Nation

Affected population: 885 (2010)
400 acres of farmland near 30 AUMs (removal sites)
Production era: 1952-1964
Waste Volumes: ~290,000 tons
NNAML Reclamation to reduce safety hazards
Hazardous substances: As, Fe, Co, Pb, Hg, Se, Th, Tl, U, V



METALS conceptual framework linking community concerns and engagement to environmental and biomedical projects; original painting by Mallery Quetawki, UNM Artist in Residence.

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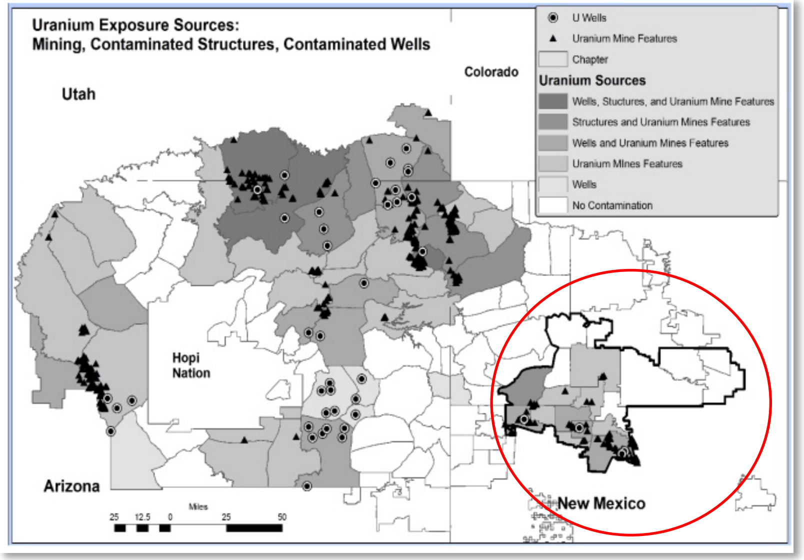
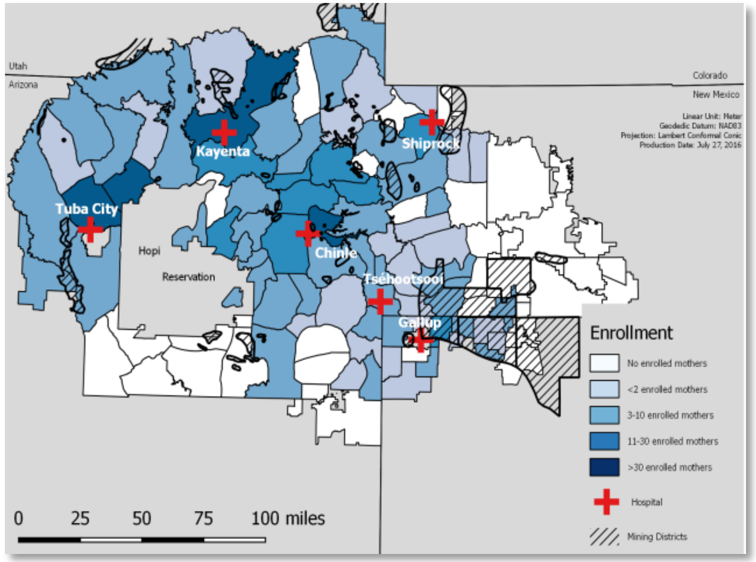
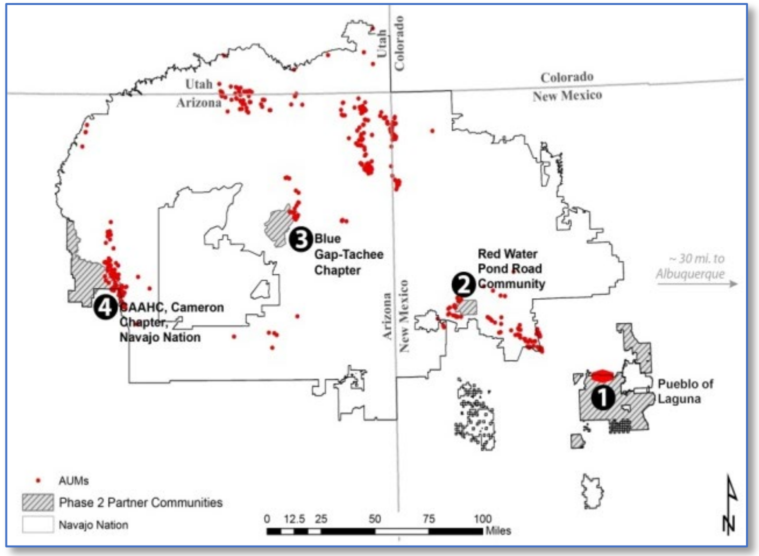
Community questions about exposures have driven UNM environmental health research







<u>DiNEH Project, 2002-2012</u>

- Does U in drinking water increase risk of kidney disease?
- Do multi-pathway exposures to metals in mine wastes increase risks of chronic disease?
- *Community-based trainings to develop study design, implementation methods, consents*

<u>Navajo Birth Cohort Study, 2010-present</u>

- Do exposures to U mine waste affect child health, development?
- Do exposures to metals in mine wastes increase chronic disease?
- *Extensive trainings to develop EH capacity among community members hired by UNM, SRIC and NNDOH*

<u>METALS SRP, 2014-present</u>

- Do mixed-metal U mine wastes contribute to air, water and farmland contamination?
- Do exposures to U wastes result in immunologic, cardiovascular, pulmonary effects?
- Status of remediation?
- *Community defines research*

UNM Population-based EH studies to ascertain exposures and health outcomes

Study	Design	Population	Target Health Outcomes
DiNEH Project, Navajo Uranium Assessment and Kidney	Cross-sectional; iterative, multi-pathway analysis	Phase I – 1,304 participants in 20 chapters of ENA; Phase II – 267 participants in blood and urine collections	▪ Chronic kidney disease ▪ Cardiovascular disease ▪ Autoimmunity
Navajo Birth Cohort Study	Longitudinal cohort	More than 1,800 mothers, fathers, babies in 3 phases across Navajo Nation	▪ Child development ▪ Metals and pre-term births ▪ Upper airway effects
Thinking Zinc	Clinical trial	52 volunteers from Churchrock and Blue Gap-Tachee communities	▪ Zn supplementation to repair metals-induced damage to DNA repair mechanisms
METALS Superfund Research Center	Laboratory animals	Community members exposed to dust from AUMs	▪ Cardiopulmonary effects of exposure to metals-laden “nanoparticles”





Common methods to ascertain exposures, health outcomes

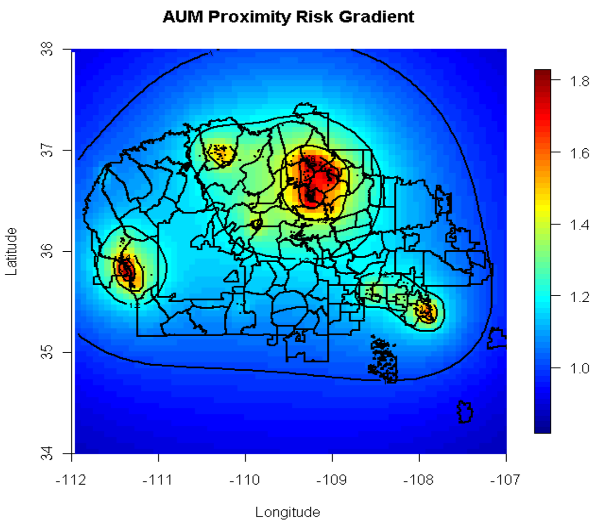
Method	DiNEH Project	NBCS-ECHO+	Thinking Zinc	UNM METALS
Surveys administered Navajo-speaking researchers	●	●	●	
Geospatial analyses (locations of homes, AUMs)	●	●	●	●
Water quality in public water systems, unregulated wells	●	●		●
Home assessments, including radiation surveys, indoor radon, indoor dusts		●		
Assessments of biomarkers of effects	●		●	
Biomonitoring (detection of metals in human tissues, including urine, blood, hair, toenails)	●	●	●	
Child developmental assessments		●		
Laboratory animal studies of environmental exposures to mine dust				●
Administration of zinc supplements to repair damage from metals exposures			●	

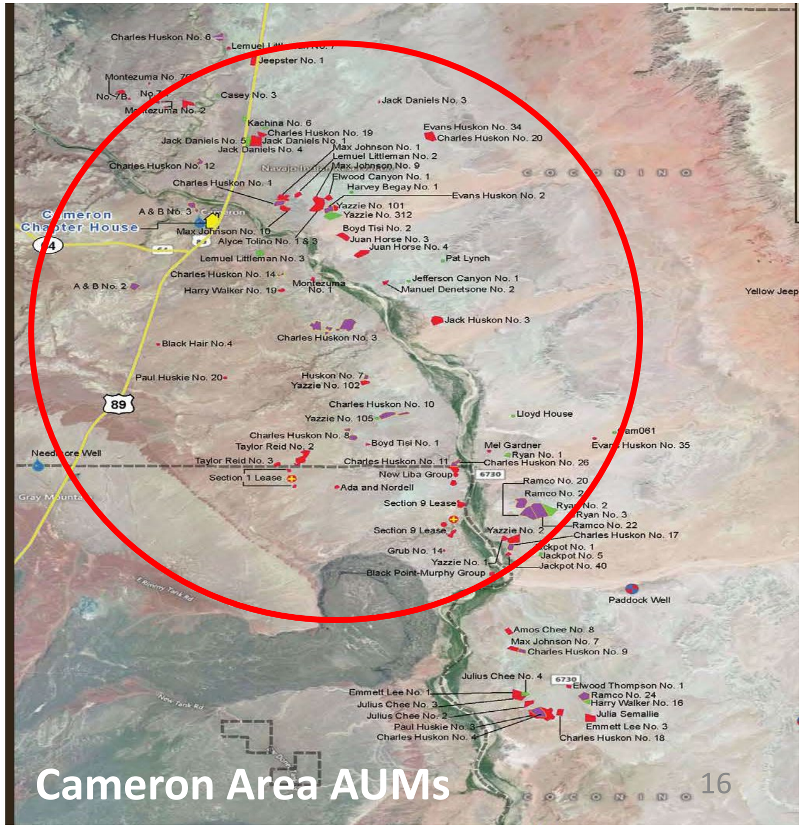
Summary of *Significant* Exposure Variables and Key Findings across UNM Environmental Health Studies (see complete chart at end)

AID = autoimmune disease; CKD = chronic kidney disease; CVD = cardiovascular disease

Exposure variables	Studies	Selected results
Promixity to AUM sites	Hund et al, 2015; Harmon et al, 2017; Erdei et al, 2019; Erdei et al, 2023	▪ CKD: Doubling risk in active mining era, 1950-1986 (10% of participants were U workers) ▪ CVD: 62%-81% increase in the risk of hypertension during legacy period (after 1986); ▪ CVD: Increased inflammatory potential measured by endothelial transcriptional responses ▪ AID: Proximity predicted autoantibody responses for women (p=0.01), all participants (p=0.0065); AuAbs markers associated with U in drinking water *below* MCL ▪ AID: Twofold increase in ANA positivity; proximity associated with clinically defined ANA response (OR*=3.07, p=0.025)
Environmental metals from biomonitoring	Erdei et al, 2022 (NBCS, N=52); Dashner-Titus et al, 2022 (Thinking Zinc N=52); Hoover et al, 2020 (NBCS, N=783); Harmon et al, 2018 (N=252)	▪ CVD: 92% of babies with detectable urine U at birth born to mothers who had urine-U levels greater than national norms; As exposure increased oxidative stress, a contributor to CVD ▪ 4-fold increase in U levels among Thinking Zinc participants ▪ AID: 7 cytokines indicative of immune dysfunction were higher than U.S. U levels (OR = 2.21 (1.08–4.52)) ▪ Pregnant Navajo women have higher U exposures than all U.S. women
Metals in drinking water	Erdei et al, 2019 (N=239); Harmon et al, 2018 (N=252); Erdei et al, 2023 (N=239) Hoover et al, 2017	▪ CVD: Consumption of U correlated with increased C-reactive protein ▪ AID: Elevated autoantibody biomarkers associated with U at levels <MCL of 30 ug/L ▪ AID: As (OR=1.79; p=0.012) and Ra (OR=1.04, p=0.001) associated with anti-dsDNA serum response for ANA positivity ▪ AID: Hg consumption associated with increased ANA response (OR=2.34; p=0.008); Ni consumption predicts increased serum anti-U1-RNP ▪ CVD: As (15.1%), U (12.5%) most frequently measured metals exceeding their drinking water standards in nearly 500 unregulated water sources on the Navajo Nation, including ~100 in Eastern Agency
Age	Erdei et al, 2023 Erdei et al, 2019	▪ Associated with increased serum ANA response (OR*=1.07, p=0.018) ▪ Associated with increased antibodies to denatured DNA

This is what "proximity" to waste sites looks like – today!





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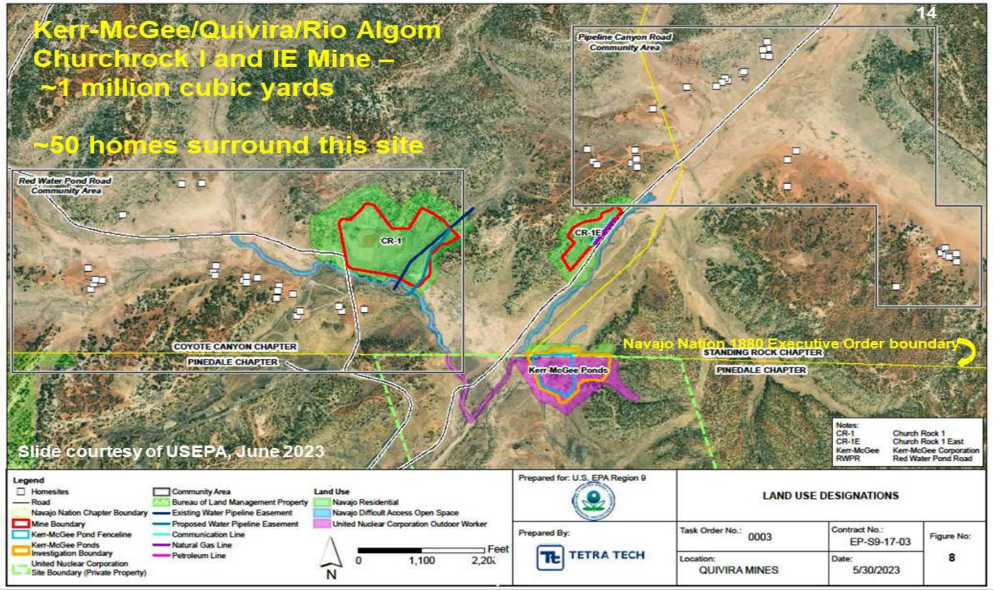
Implications for remediation

- Heightened policy attention when Uranium Legacy is seen as a long-term disaster
- Prioritize remediation of AUM waste sites near where people live
- Evaluate synergism between kidney disease and cardiovascular disease in the Navajo population
- Consider cultural practices that tie Indigenous people to their homelands
- Biomonitoring can supplement regulatory risk assessment
- Embrace environmental health findings in remediation decision-making
- Consolidate wastes into fewer sites to reduce exposures, preserve future land uses, safely contain wastes for thousands of years
- Federal Government should take full responsibility for remediation of defense-related uranium mines, which comprised about 75% of all AUMs on Navajo Nation



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