Water Characterization of Navajo Unregulated Water Sources

Jani C. Ingram PhD – Chemistry & Biochemistry, Northern Arizona University
Joseph Hoover PhD – Environmental Science, University of Arizona
Daniel Beene – Geography & Environmental Studies, University of New Mexico
Tommy Rock PhD – Geosciences, Princeton University
Jonathan Credo PhD – Clinical Translational Sciences, University of Arizona
Lindsey Jones – Water Infrastructure Finance Authority

GREETINGS FROM FLAGSTAFF

Northern Arizona University sits at the base of the sacred mountains, on homelands sacred to Native Americans throughout the region. We honor their past, present, and future generations, who have lived here for millennia and will forever call this place home.

Who am I?

Born in Kingman, AZ
to Janis and Dave
Cunningham

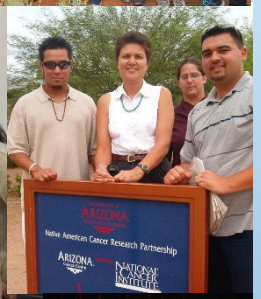
The Ingram Family

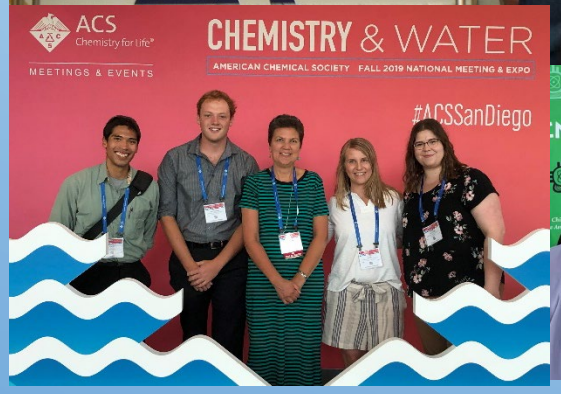
Mother's clans: Maternal clan - Náneesht'ézhi (Charcoal-Streaked)
Paternal clan – Kinłichíi'niĺ (Red House)

Father's background: Mother – German
Father – European mix

Mother of Jordan, Joshua, and Jalisa – married to James Ingram

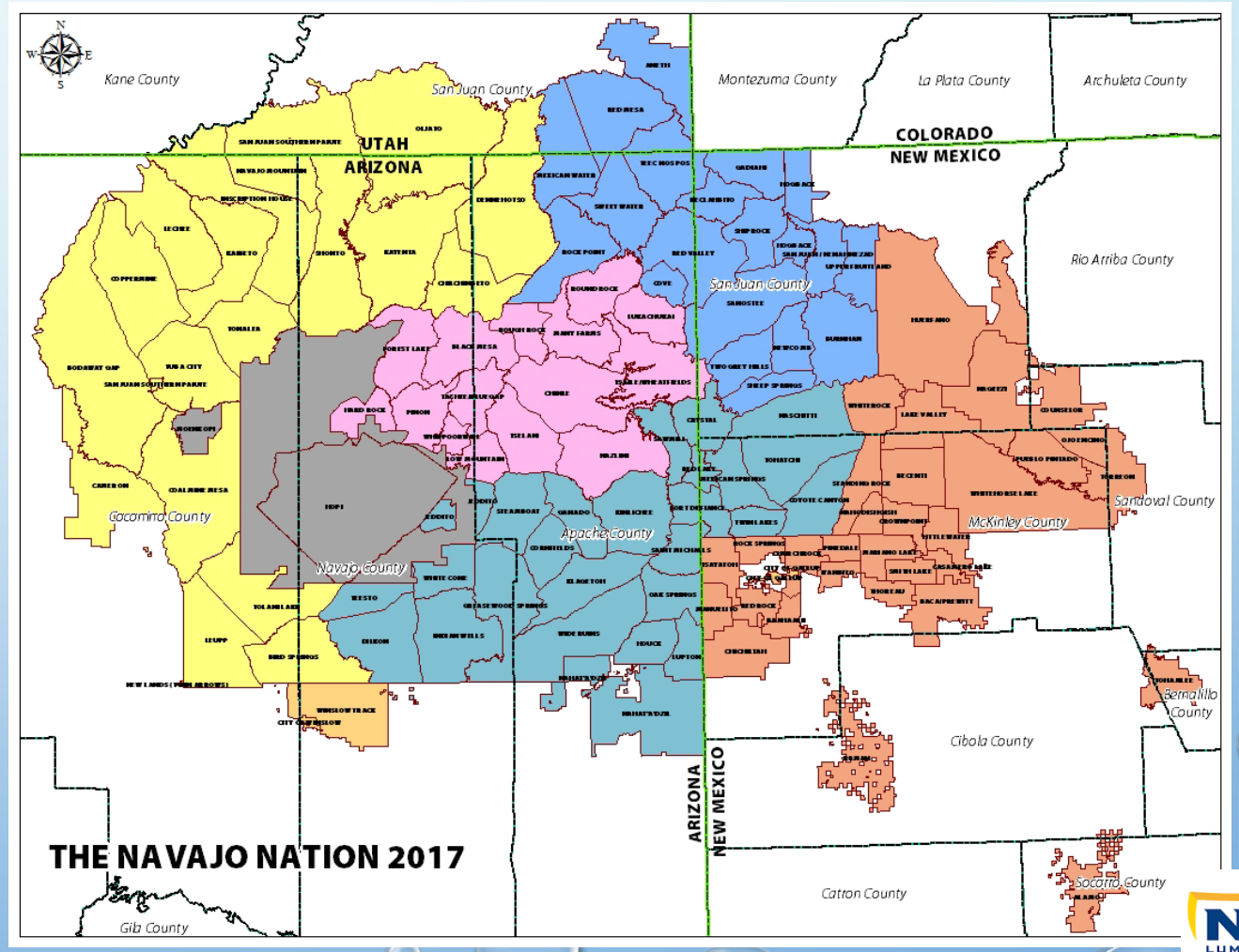
My Chemistry Kids





NAVAJO NATION - DINÉ BIKÉYAH

- Located in 4-Corners Southwest U.S.
- 27,000 square miles
- Reservation established according to the Treaty of 1868
- Sovereign Nation established in 1923
- Capital located in Window Rock, AZ
- Five Agencies and 110 Chapters



DINÉ (NAVAJO) BACKGROUND

- Diné’ is what Navajo people call themselves
- Population: 165,158 on Reservation (total = 399,494) as of 2021
- Median Household Income: $37,500
- Unemployment: 14.6 %
- Poverty: 37.5 % lives below the poverty rate
- Education (for ages 25+): 35.3 % high school degree 5.2 % college degree
- Land mass: 17.5 million acres (size of West Virginia)
- Infrastructure: 20 – 30 % of households on reservation are without running water or power
- Ranchers/Sheep Herders
    - https://naair.arizona.edu/sites/default/files/Navajo%20Nation%20Census%20Data_0.pdf

WATER INSECURITY ON NAVAJO LANDS

- Lack of infrastructure
- Arid climate
- Water rights issues
- Drought
- Water hauling from non-regulated (livestock wells)
- Typical cost for water users in urban areas is $600 per acre-foot of water
- Navajo people who depend on hauling water pay about 70 times this amount ($43,000 per acre-foot)
- COVID pandemic

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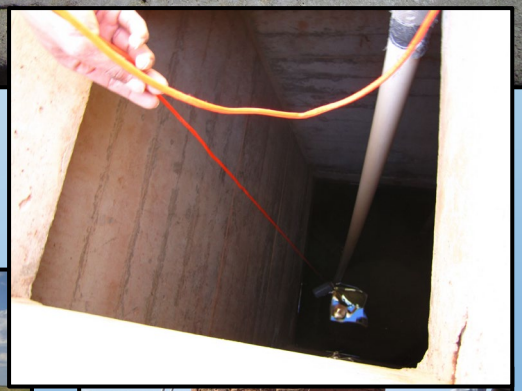
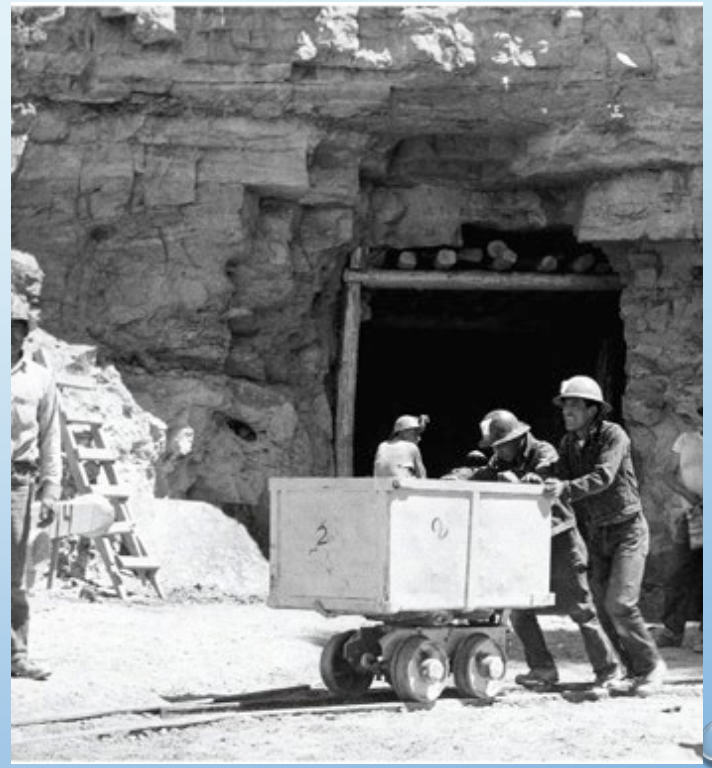
EXAMPLES OF NON-REGULATED WELLS



URANIUM MINING ON NAVAJO

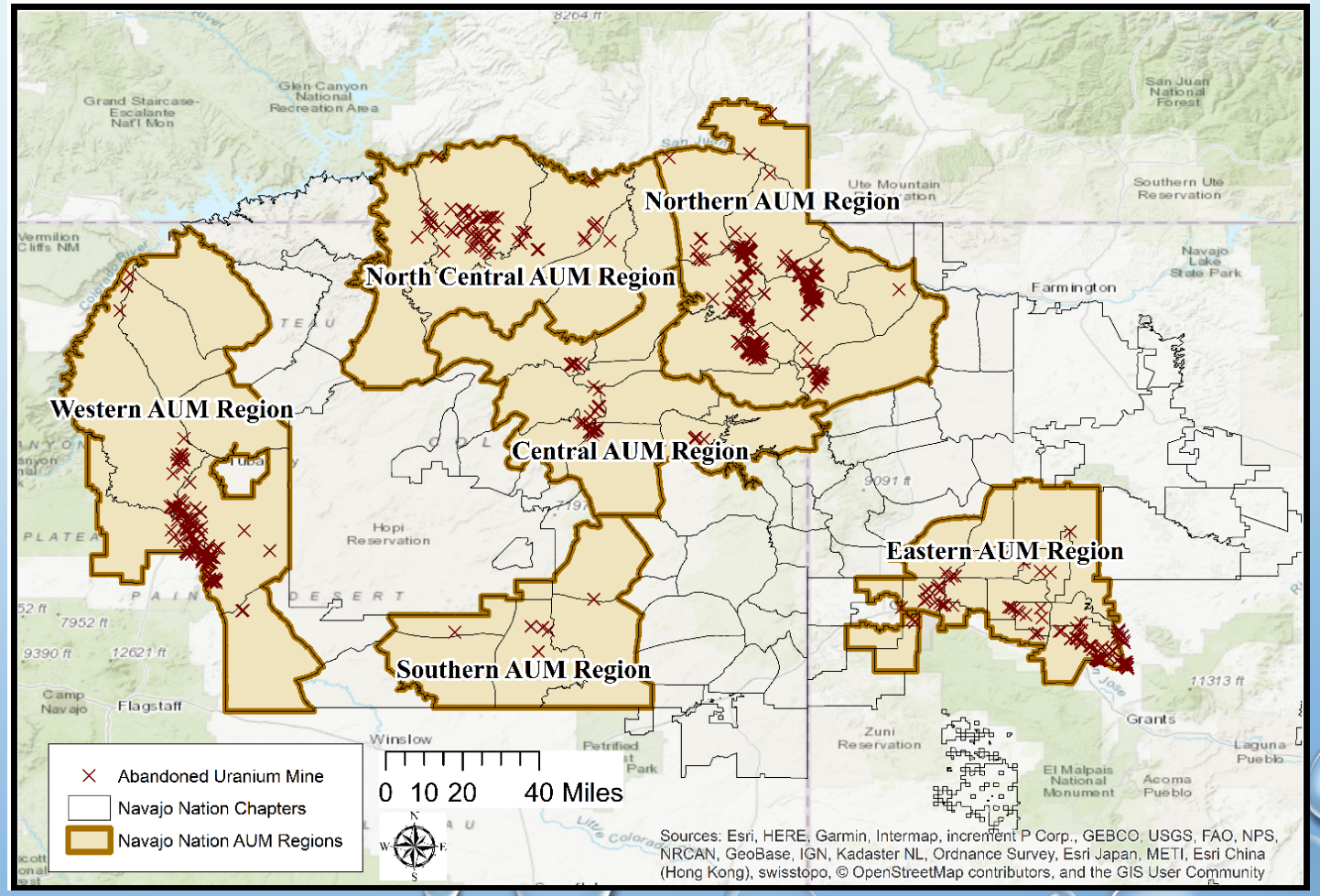
- Approval of Manhattan Project – 1942
- Uranium mining boom
  - Mid to late 1900's
- Mining activity on Colorado Plateau
  - Near Four Corners area, in AZ, NM, UT, and CO
- Large amounts of radioactive waste
- Navajo people facing serious health consequences



http://buffalopost.net/?tag=radiation-exposure-compensation-act

URANIUM MINING ON NAVAJO

- Over 500 AUM sites and over 1,200 mine features spread throughout NN
- Contamination of groundwater from U mining – erosion of tailing piles and from open pit mining below the water table



U.S. URANIUM MINING POLICIES

- US EPA's **Superfund Program** was created to comply with the Comprehensive Environmental Response, Compensation, and Liability Act (**CERCLA**) – 1980

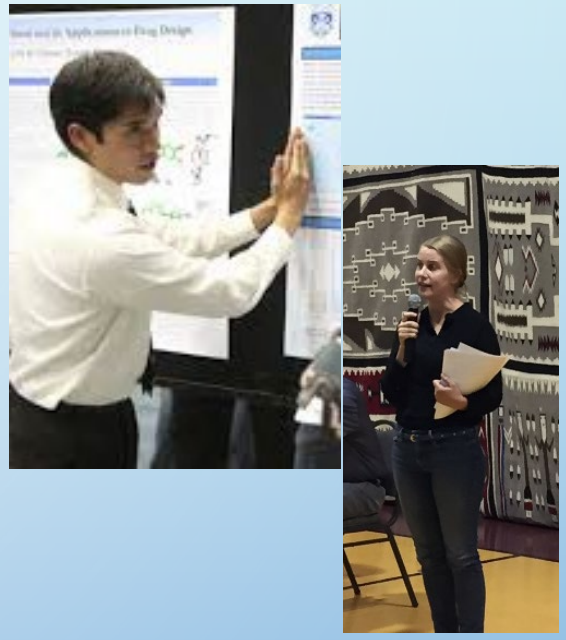
- Uranium Mill Tailings Radiation Control Act (**UMTRCA**) – 1978
    - Uranium Mill Tailings Remedial Action (**UMTRA**) Groundwater Project – 1991

- Diné Natural Resources Protection Act (**DNRPA**) – 2005
    - Reinforces the Navajo Fundamental, Traditional, and Natural Laws
    - Highlights importance of protecting environment for cultural and spiritual reasons

"No Uranium" sign

INGRAM LAB WATER RESEARCH ON NAVAJO

- First unregulated water samples collected in 2003
- Water sampling and analyses have been ongoing
- Water sampling expanded based on community request and student interest
- Dissemination of results to the community critical
- Lesson learned – partner with the community for sampling



Two publications that exemplify the research:

- "Quantification of Elemental Contaminants in Unregulated Water across Western Navajo Nation", **J. Credo**, J. Torkelson, T. Rock, J. C. Ingram, International Journal of Environmental Research and Public Health, 16, 2019, 2727, doi:10.3390/ijerph16152727.
- "Dissolved Uranium and Arsenic in Unregulated Groundwater Sources – Western Navajo Nation", **L. Jones**, J. Credo, R. Parnell, J.C. Ingram, Journal of Contemporary Water Research & Education, 169, 2020, 27-43.

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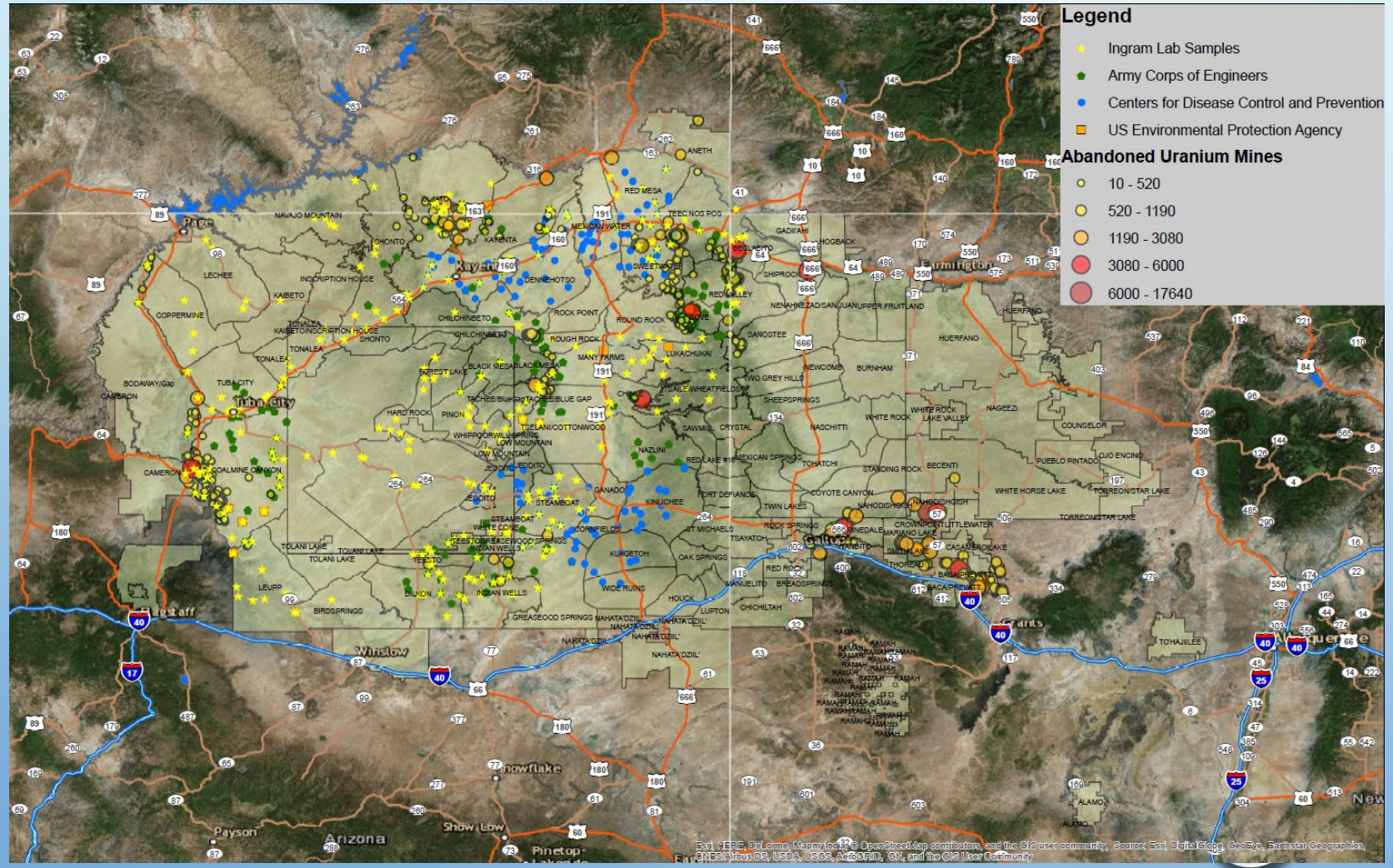
UNREGULATED WATER COLLECTION SITES



Results from Credo publication

★ Denotes sites sampled by Ingram lab

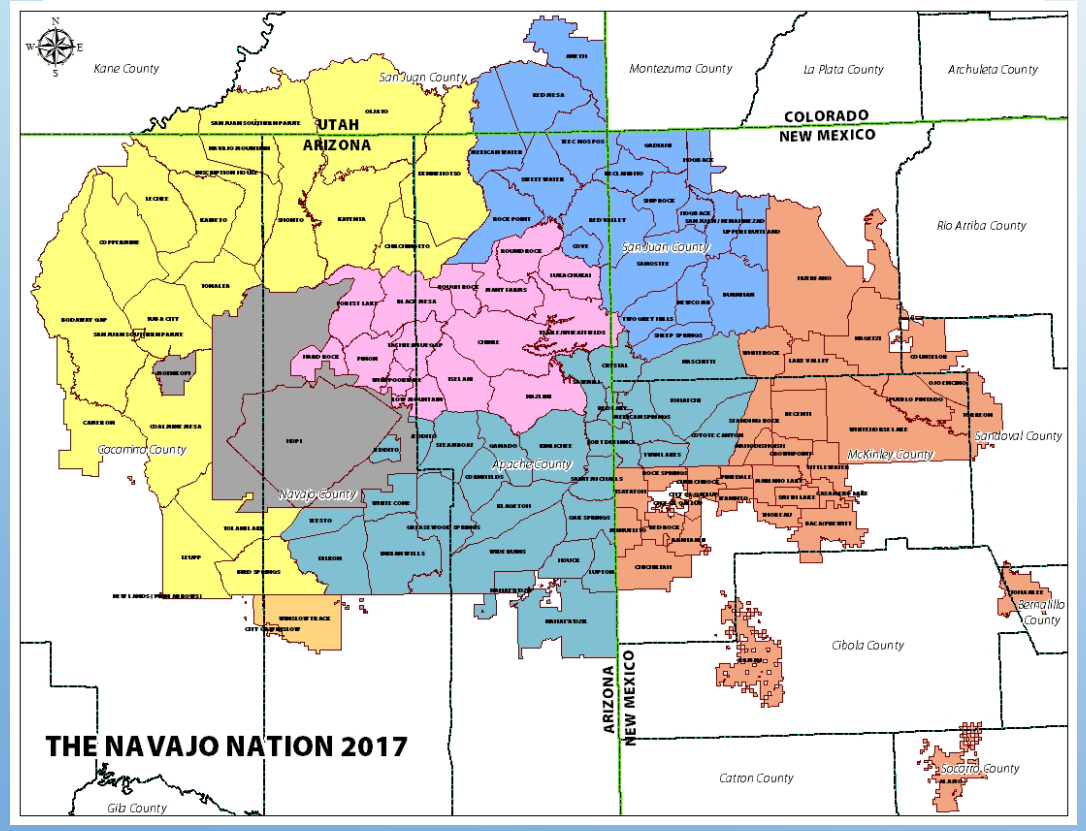
NAU LUMBERJACKS

List of 21 elements analyzed by ICP-MS (inductively coupled plasma mass spectrometry) reporting the maximum, minimum, average, and median values

Element	Max (µg/L)	Min (µg/L)	Average (µg/L)	Median (µg/L)
V	520	B.D.	81.70	67.30
Ca	430	0.35	44.7	25.6
As	190	0.03	8.21	1.99
Mn	14700	0.10	164	3.44
Li	630	3.02	63.3	37.6
U	490	0.04	14.1	3.05
Al	64600	2.16	556	12.1
Mo	1190	B.D.	27.2	2.89
Sr	10300	18.9	1160	478
Fe	605	0.02	61.5	23.1
Ni	560	0.02	6.42	1.09
Sn	2.50	0.01	0.53	0.40
Be	60.3	B.D.	0.50	0.00
Cd	11.1	0.01	0.30	0.05
Zn	3900	3.38	197	48.1
Hg	B.D.	B.D.	B.D.	B.D.
Cu	26.0	0.02	2.80	1.21
Ba	1200	7.91	177	93.7
Cr	12.1	0.03	0.94	0.47
Sb	2.80	0.03	0.33	0.27
Pb	9.25	0.02	0.66	0.10

- 296 water samples from unregulated sources on the Navajo Nation were sampled from 2013 through 2017
- All site samples two times minimum
- Water analyzed by inductively coupled plasma mass spectrometry and flame atomic absorption spectroscopy
- National Institute of Standards and Technology Standard Reference Material 1640a (NIST 1640a), field and instrument blanks, and check standards analyzed with samples

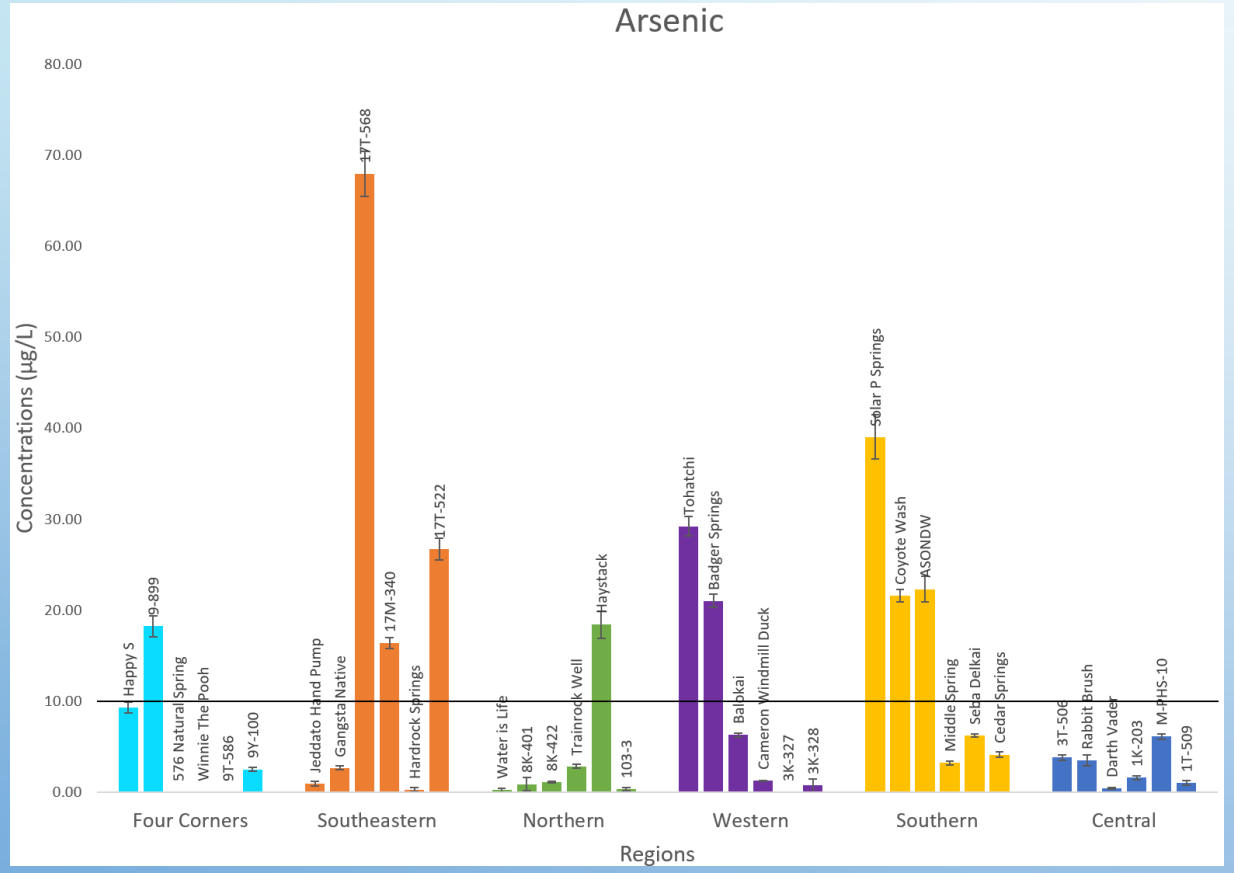
Distribution of As, U, V, Mn, Ca, and Li concerning guideline comparisons across the four Navajo Agencies

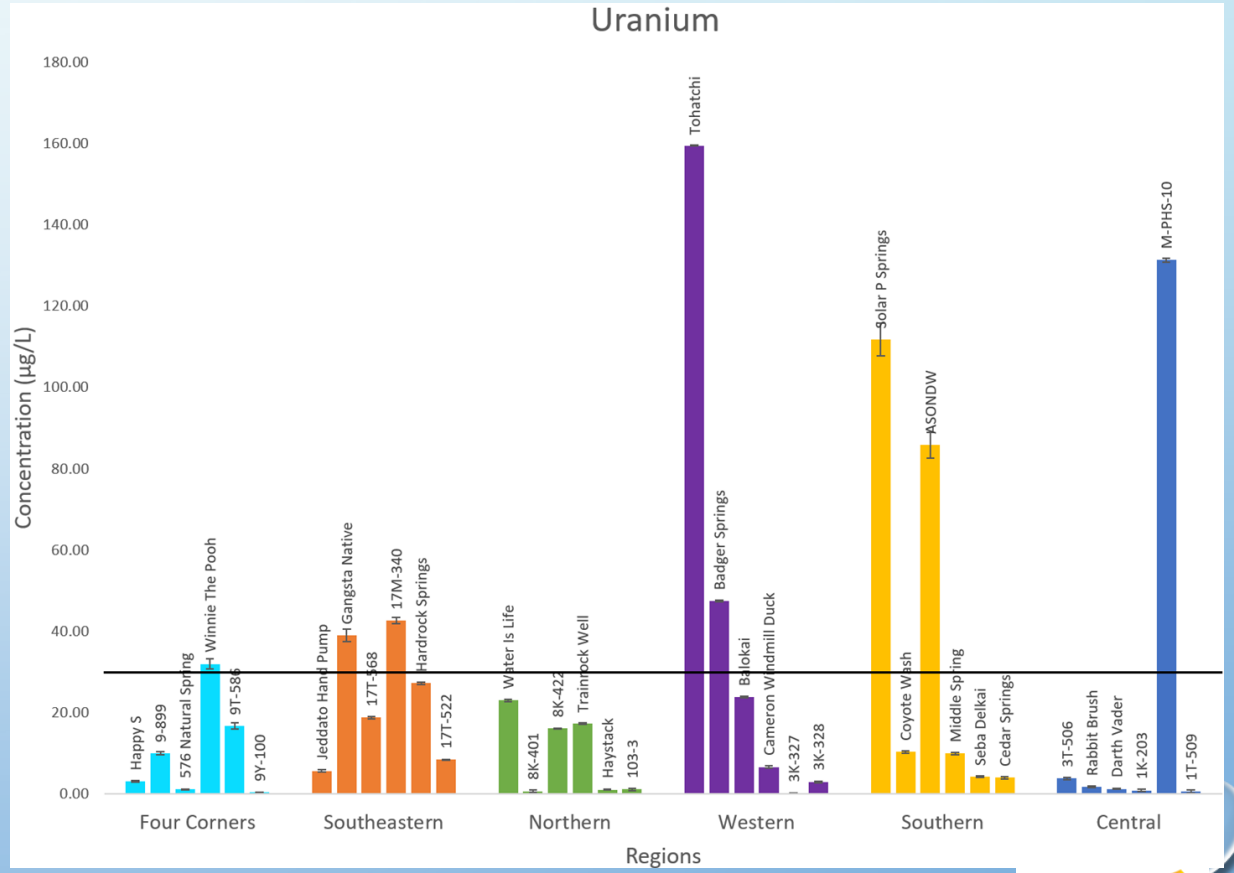


		Agency				
Element	Title	Chinle	Fort Defiance	Shiprock	Western	Totals
Arsenic	Above	3	23	3	11	40
	Approaching	0	4	0	2	6
	Below	31	29	10	89	159
	B.D.	11	2	2	15	30
	Totals	45	58	15	117	235
Uranium	Above	3	7	1	7	18
	Approaching	3	3	0	5	11
	Below	32	44	14	93	183
	B.D.	6	2	0	11	19
	Totals	44	56	15	116	231
Vanadium	Above	24	26	7	40	97
	Approaching	0	0	0	2	2
	Below	5	1	1	11	18
	B.D.	2	2	0	0	4
	Totals	31	29	8	53	121
Manganese	Above	19	4	1	5	29
	Approaching	1	0	0	0	1
	Below	12	25	7	47	91
	B.D.	0	0	0	0	0
	Totals	32	29	8	52	121
Calcium	Above	26	11	1	31	69
	Approaching	0	0	0	4	4
	Below	8	18	6	19	51
	B.D.	0	0	0	0	0
	Totals	34	29	7	54	124
Lithium	Above	19	13	5	19	56
	Approaching	6	5	1	3	15
	Below	6	12	2	30	50
	B.D.	0	0	0	0	0
	Totals	31	30	8	52	121

B.D. = Below Detection

EXAMPLES OF AS AND U RESULTS



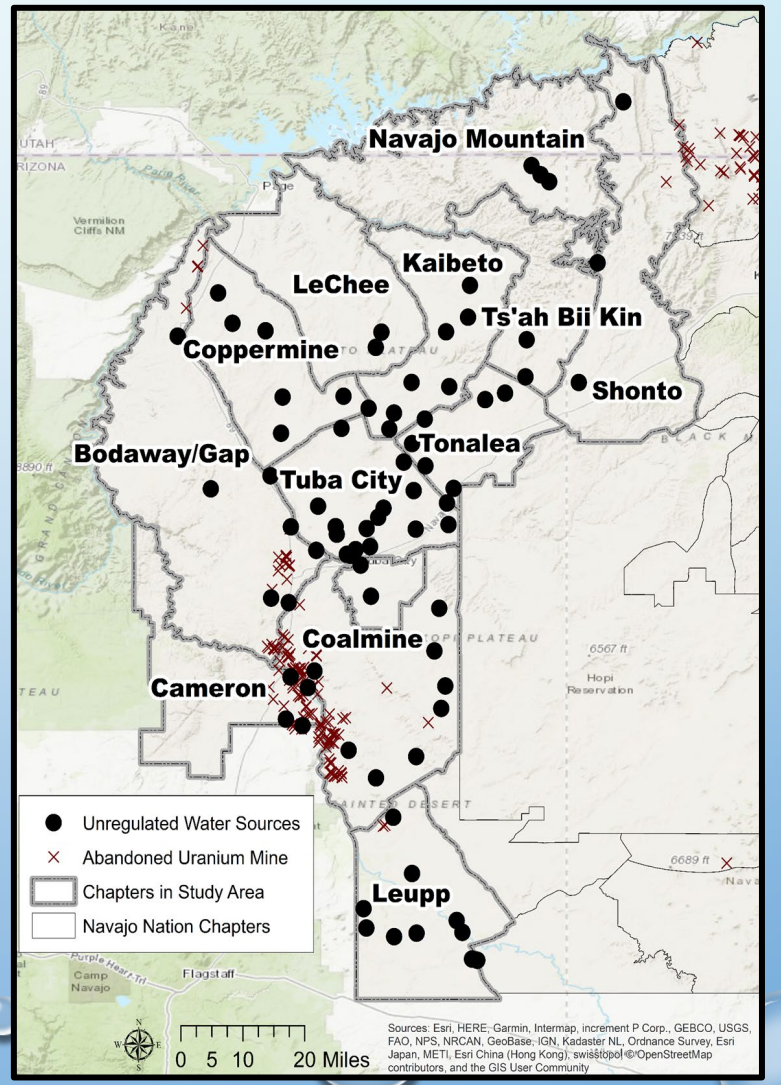


Horizontal lines denote US EPA Maximum Contaminant Levels

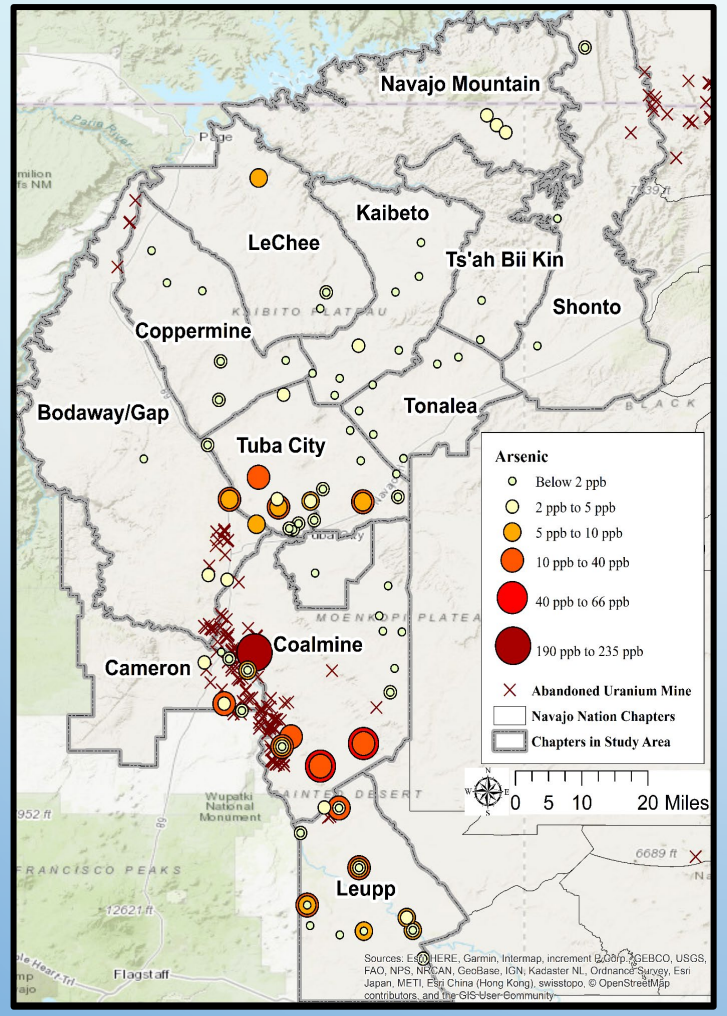
WESTERN NAVAJO As AND U WORK

- Uranium mining in Western Region from 1951 to 1963
- 126 abandoned uranium mine structures
- Majority of abandoned uranium mine sites near Little Colorado River
- Most mines open pits, small trenches to large open pits up to 2,400 ft. x 250 ft. (4 deep vertical shafts)
- 82 unregulated water sources tested

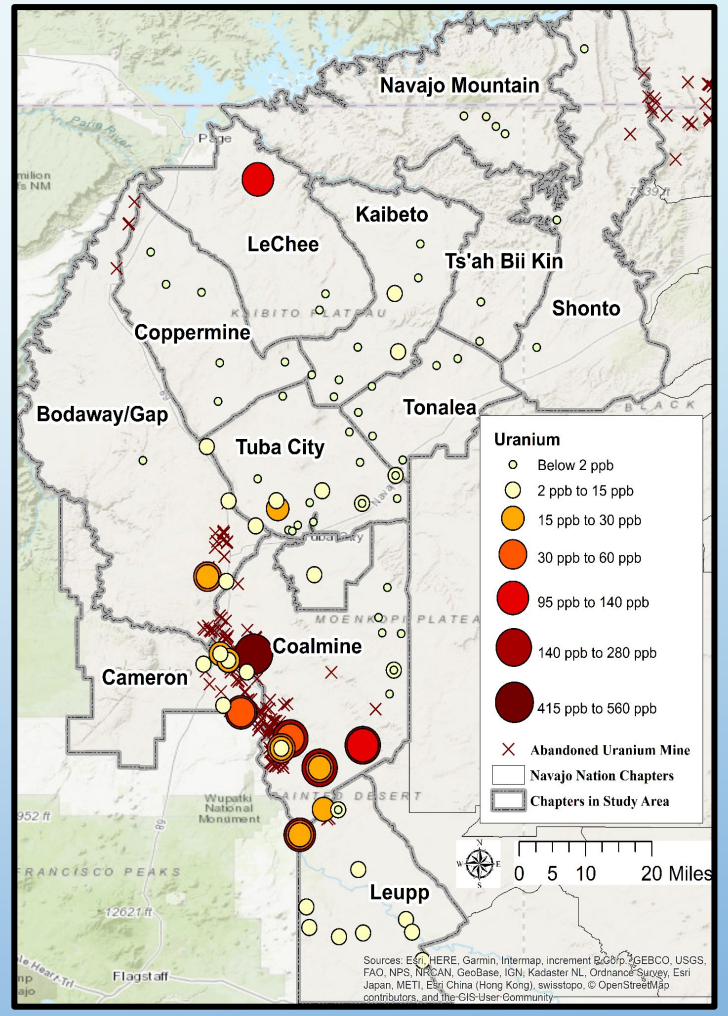
Thesis research: Lindsey Jones



As AND U RISK MAPS FOR WESTERN NAVAJO



Arsenic



Uranium

Example of report provided to Chapters in Western Navajo on water results

UNREGULATED GROUNDWATER QUALITY
WESTERN NAVAJO NATION

2018

Prepared by Lindsey Jones, Northern Arizona University

Principal Investigator: Jani C. Ingram, PhD, Northern Arizona University

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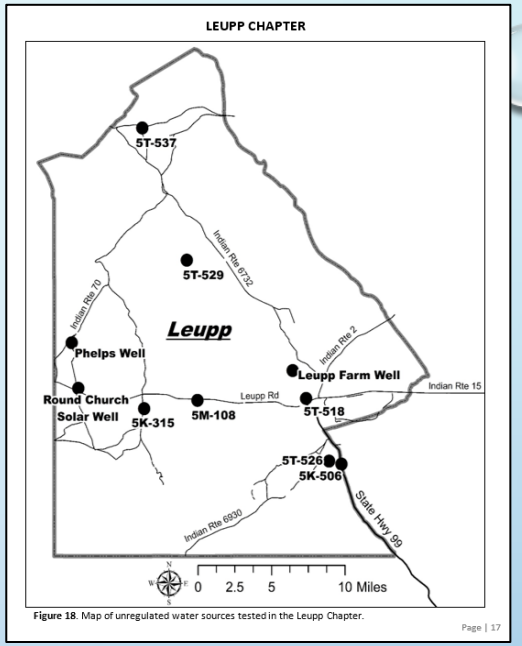


Figure 18. Map of unregulated water sources tested in the Leupp Chapter.

LEUPP CHAPTER

Ten unregulated water sources were tested in the Leupp Chapter (Figure 18). All samples were below the MCL for uranium (Figures 19 and 20). Samples that exceeded the MCL for arsenic are shown in figure 19. Seasonal variability was important for these wells since the June samples were all below the MCL while the August and November samples were either approaching or exceeded the MCL for arsenic. **Well 5T-529** was sampled from the open tank as well from the spigot at the trough. Well 5T-529 had high chloride levels (400 ppm to 530 ppm) and an average conductivity of 2,636 µs/cm. **Well 5T-537** showed the greatest increase in arsenic from June to November. Further, it had very high levels of chloride (1,500 ppm to 1,680 ppm). The conductivity of Phelp's **Well** ranged between 3,090 µs/cm and 3,190 µs/cm, **Well 5K-315** ranged between 774 µs/cm and 932 µs/cm, **Well 5K-506** ranged between 1,153 µs/cm and 1,309 µs/cm, **Well 5T-518** ranged between 1,924 µs/cm and 2,087 µs/cm, and **Well 5T-526** ranged between 1,479 µs/cm and 1,593 µs/cm. **Well 5M-108** had chloride levels between 276 ppm and 345 ppm and an average conductivity of 2,122 µs/cm. **Leupp Farm Well** had a chloride level of 270 ppm during the August sample (June and November samples were not tested for chloride) and an average conductivity of 1,829 µs/cm. Other water sources had relatively low levels of major cations and anions or were they were not analyzed.

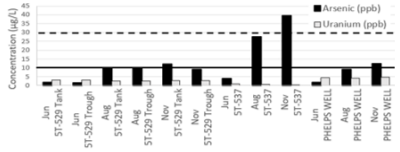


Figure 19. Arsenic and uranium concentrations in parts per billion (ppb) for Leupp Chapter unregulated water sources. The solid line is the MCL for arsenic (10 ppb) and the dashed line is the MCL for uranium (30 ppb).

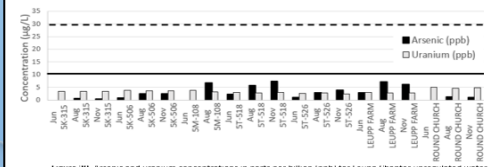


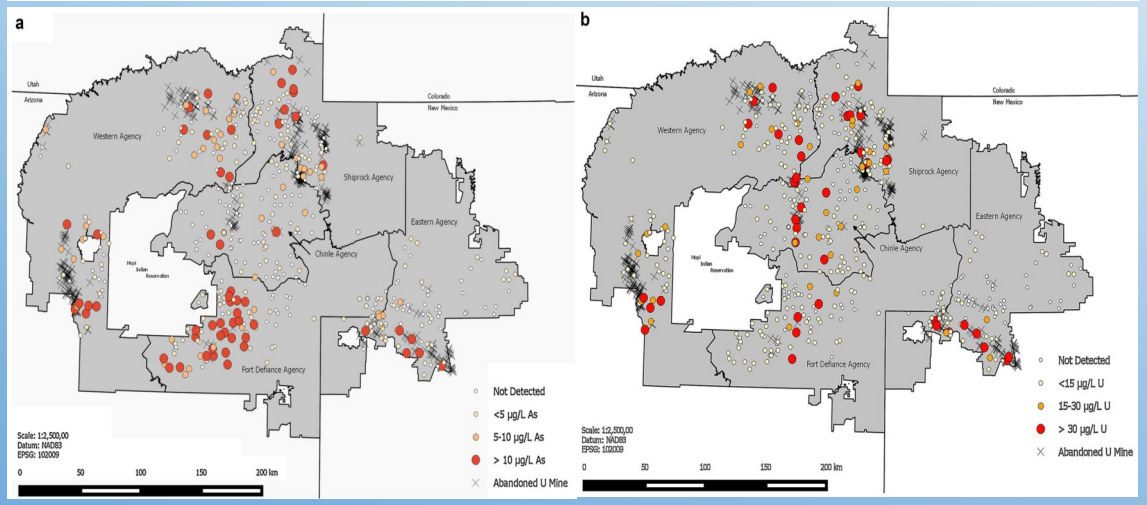
Figure 20. Arsenic and uranium concentrations in parts per billion (ppb) for Leupp Chapter unregulated water sources. The solid line is the MCL for arsenic (10 ppb) and the dashed line is the MCL for uranium (30 ppb).

NAVAJO WATER WORK BY UNIVERSITY OF NEW MEXICO

ORIGINAL PAPER

Elevated Arsenic and Uranium Concentrations in Unregulated Water Sources on the Navajo Nation, USA

Joseph Hoover[1] · Melissa Gonzales[2] · Chris Shuey[3] · Yolanda Barney[4] · Johnnye Lewis[1]



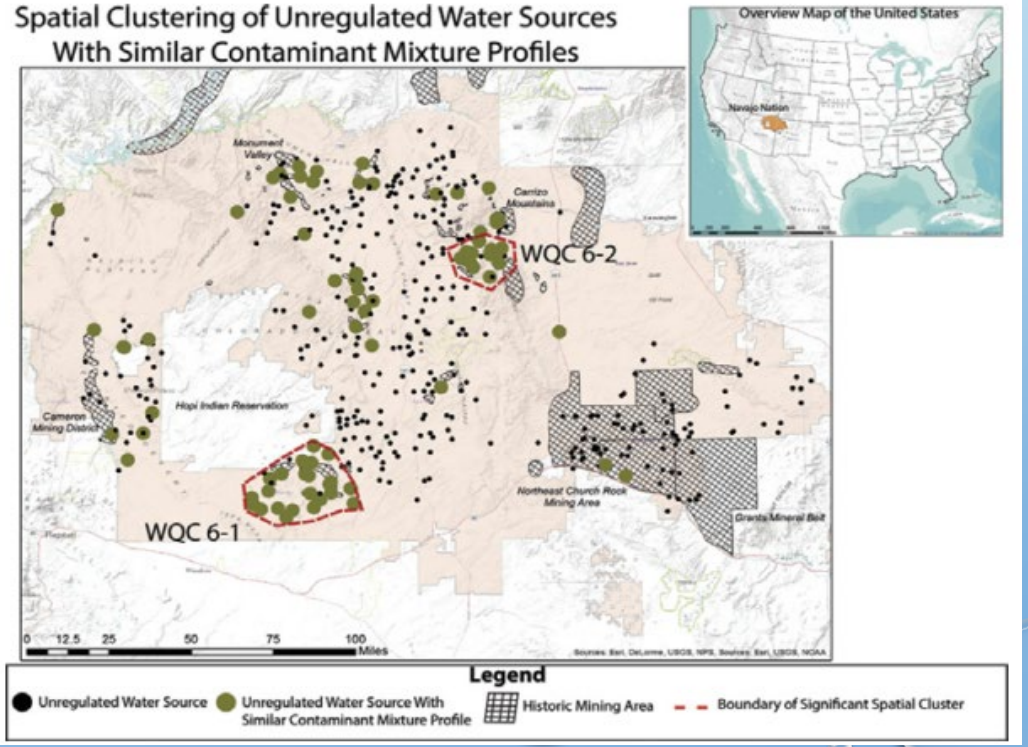
Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Spatial clustering of metal and metalloid mixtures in unregulated water sources on the Navajo Nation – Arizona, New Mexico, and Utah, USA

Joseph H. Hoover [a,*], Eric Coker [b], Yolanda Barney [c], Chris Shuey [d], Johnnye Lewis [a]



WORKING WITH UNIVERSITY OF NEW MEXICO ON NAVAJO WATER DATABASE

- In 2018, Ingram lab began working with the University of New Mexico – Dr. Johnnye Lewis group on combining water chemistry results from multiple sources into a single database.
- Dr. Joe Hoover (formerly a post-doctoral fellow at UNM now at the University of Arizona) and Mr. Daniel Beene worked with the Ingram lab to develop a database combining the NAU and UNM water data to be provided to the Navajo Nation.
- Combined database close to completion at the end of 2019

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COMPILED WATER QUALITY RESULTS FROM MANY SOURCES

DEI DINÉ ENVIRONMENTAL INSTITUTE

Tolani Lake Enterprises

Iiná Nizhóní

Navajo Nation Environmental Protection Agency

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

USGS science for a changing world U.S. Geological Survey

SOUTHWEST RESEARCH AND INFORMATION CENTER

CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

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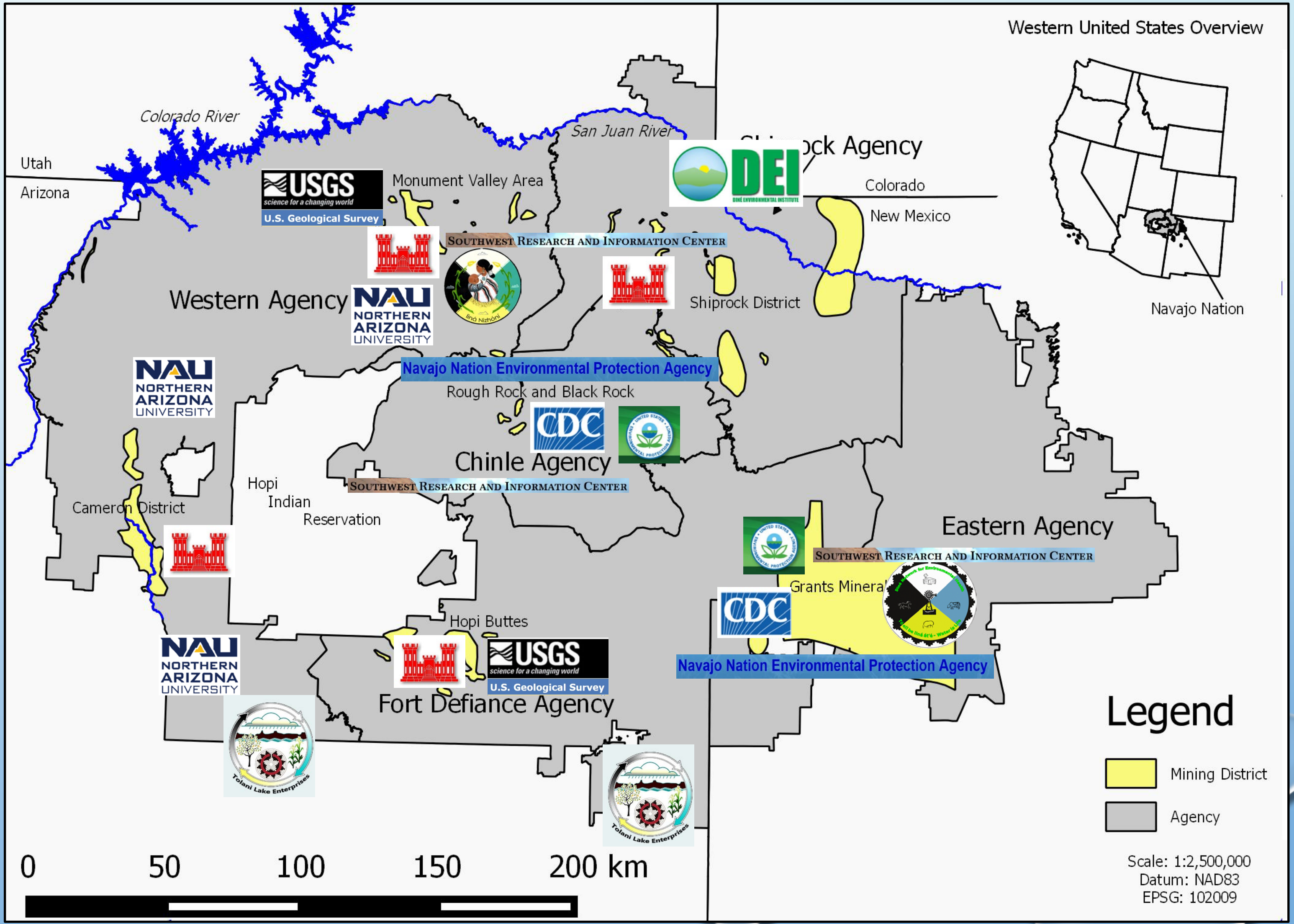
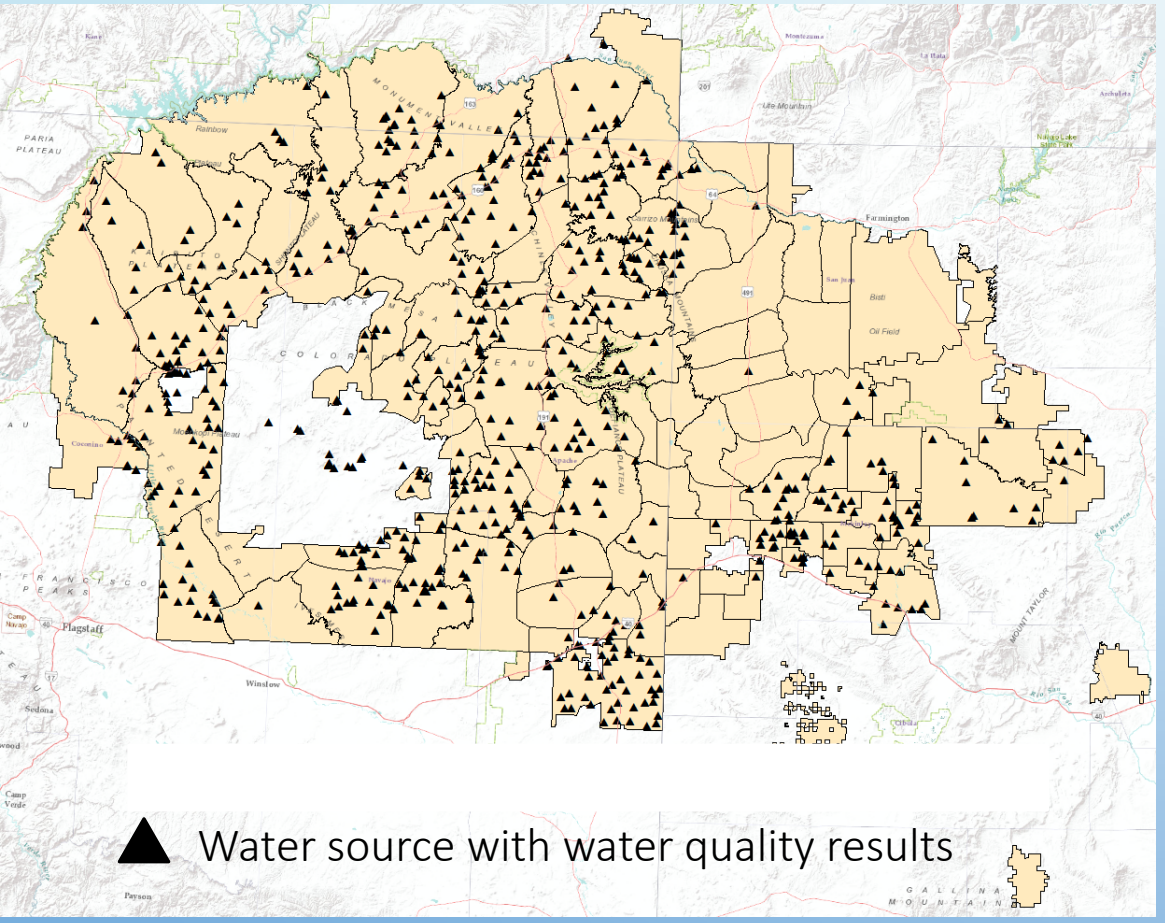
Diné Network for Environmental Health
Tó éí be iiná át'é - Water is Life



WATER SOURCE LOCATIONS ON NAVAJO NATION FROM COMPILED DATABASE



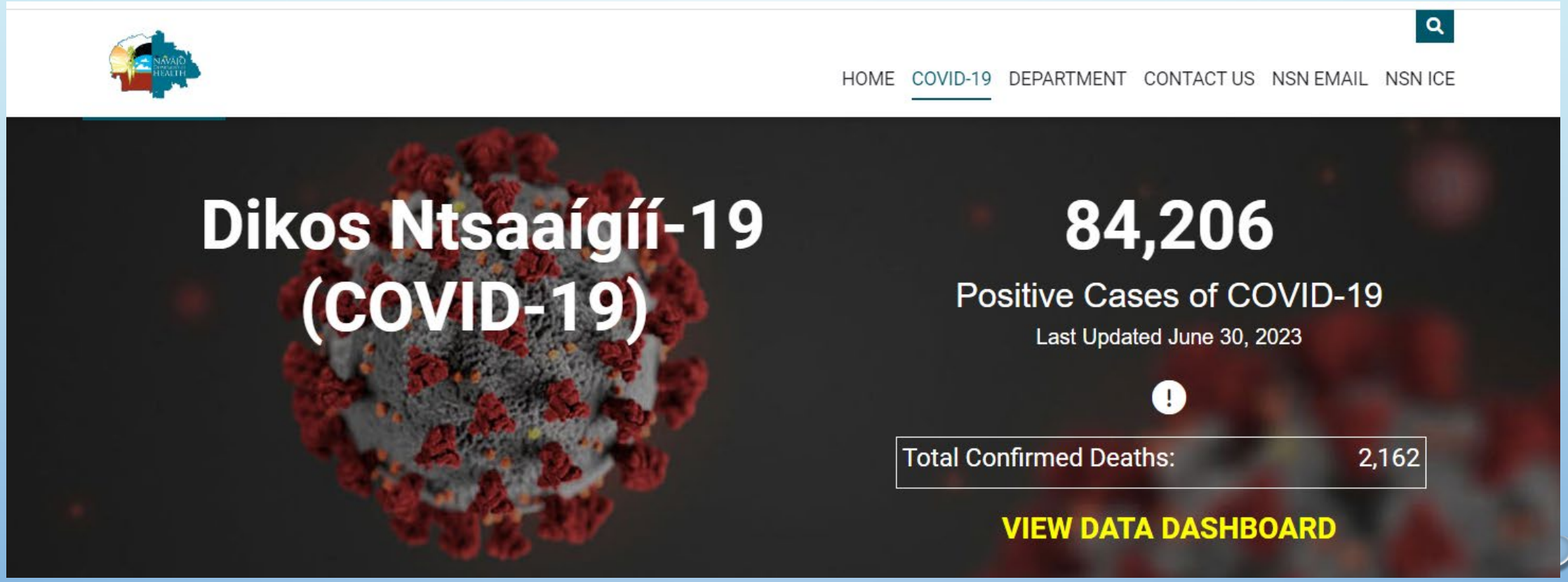
Data from 1,054 water sources for 158 analytes

Analyte Class	Water sources with measurements (N)
Primary drinking water standards	994
Secondary drinking water standards	867
Water chemistry	724
Radionuclides*	288
Other analytes and measurements*	730

*analytes that are not regulated by Safe Drinking Water Act

Database primarily comprised of unregulated sources, also includes information from some regulated water sources

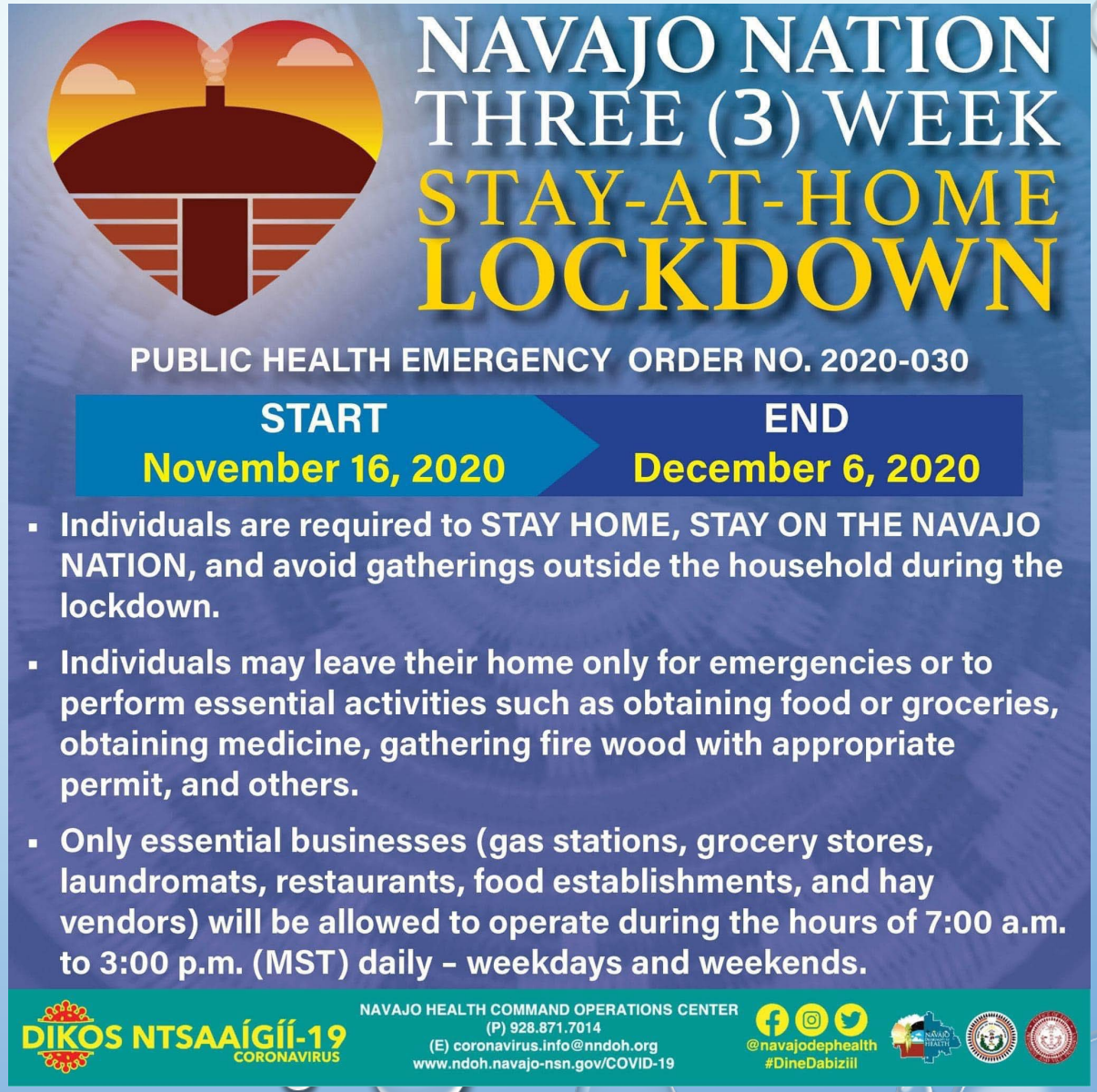
COVID PANDEMIC - NAVAJO NATION



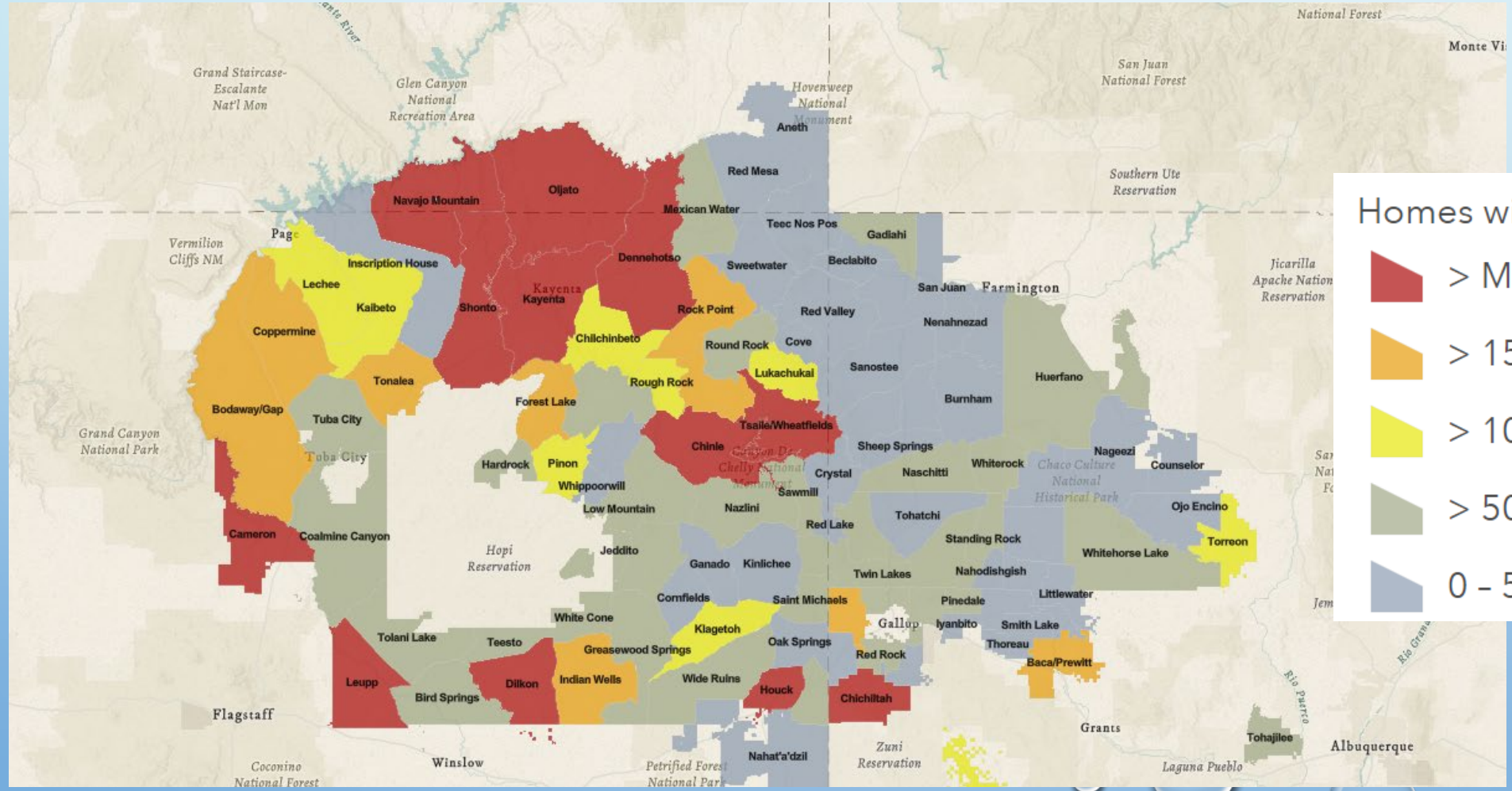
The Navajo Nation had the highest rate of Covid-19 infections per capita in the United States, plunging the largest Native American tribe into turmoil.

Impact of Pandemic and Water Issue on Navajo Nation

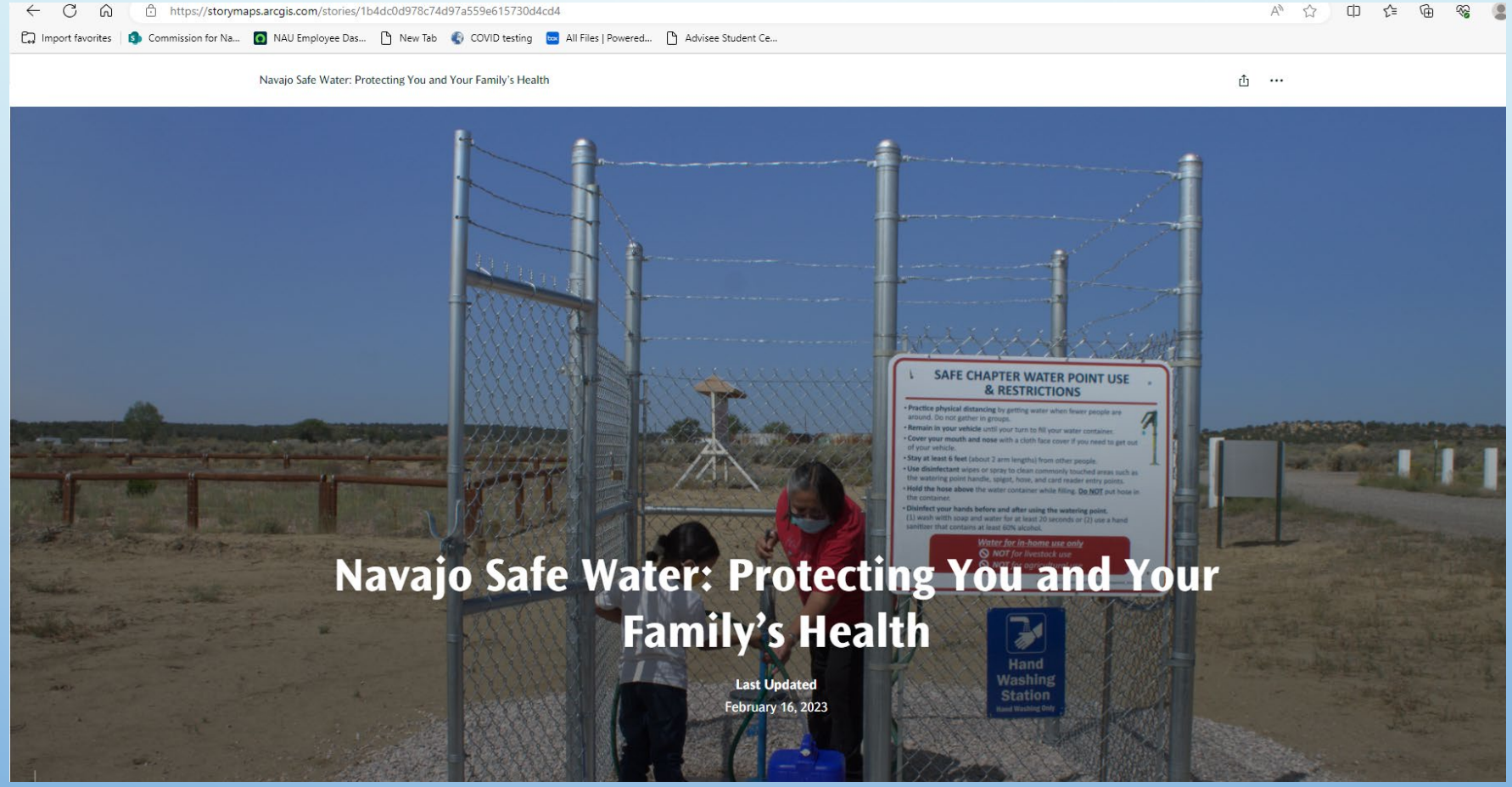
- ~30% of households have no running water
- Hauling water hampered by lockdown and curfews



NAVAJO NATION WATER INSECURITY

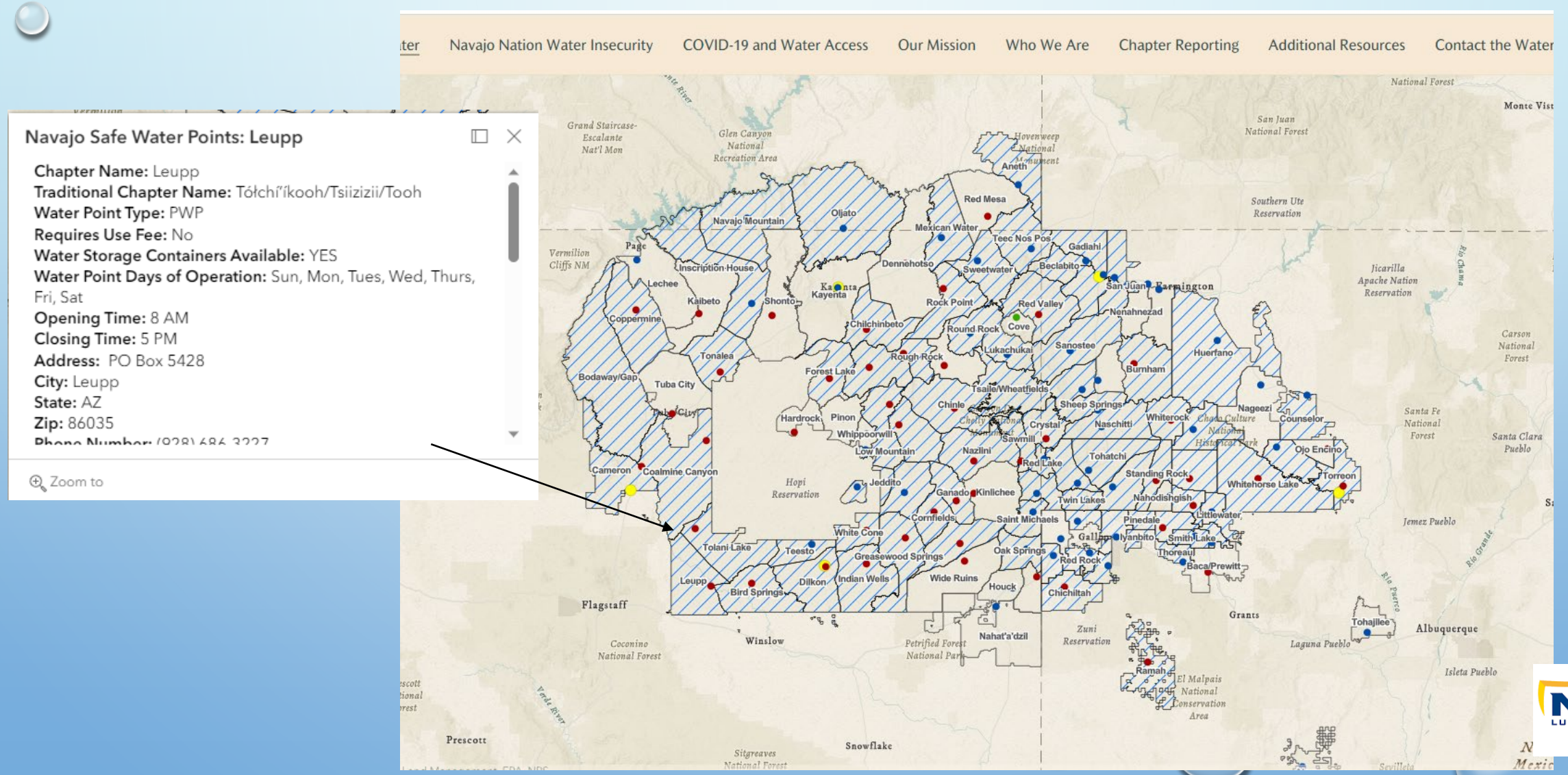


DATABASE TO WEBSITE: NAVAJO SAFE WATER



Website: Navajo Safe Water: Protecting You and Your Family's Health (arcgis.com)

INTERACTIVE MAP – WHERE TO FIND SAFE WATER



DISSEMINATION TO COMMUNITIES

- Objectives of dissemination are:
  - provide the results to the community
  - dialogue about the results
  - learn more about the environmental concerns for potential future research projects.
- Three different dissemination approaches utilized:
  - x radio announcements and flyers announcing dissemination meetings
  - ✓ work with a grassroots organization to organize report-back meetings
  - ✓ development of a booklet for distribution to communities

"Approaches for Disseminating Environmental Research Findings to Navajo Communities", T. Rock, L. Jones, J.C. Ingram, International Journal of Environmental Research and Public Health, 2021, 18, 6753-6760, (https://doi.org/10.3390/ijerph18136753)

ACKNOWLEDGMENTS

- Technical Assistance
  - Dr. Michael Ketterer, Northern Arizona University

- Collaborators and approvals
  - Navajo Nation communities and government
  - Dr. Johnnye Lewis, University of New Mexico
  - Navajo Water Access Coordination Group
  - Ingram lab students

- Funding
  - National Institute of Environmental Health Sciences and the US Environmental Protection Agency – Center for Indigenous Environmental Health Research (P50ES026089-01 and 289030)
  - National Cancer Institute - Native American Cancer Prevention Program (U54CA143925)
  - National Institute of General Medical Sciences – Training Grants at NAU
  - US Environmental Protection Agency (95437709 and 99T54301)

QUESTIONS