Groundwater Quality Along the Puerco River in the Sanders, AZ Area: A Draft Proposal for a Community-Research Partnership to Assess Possible Impacts of Past Uranium Mine Water Discharges

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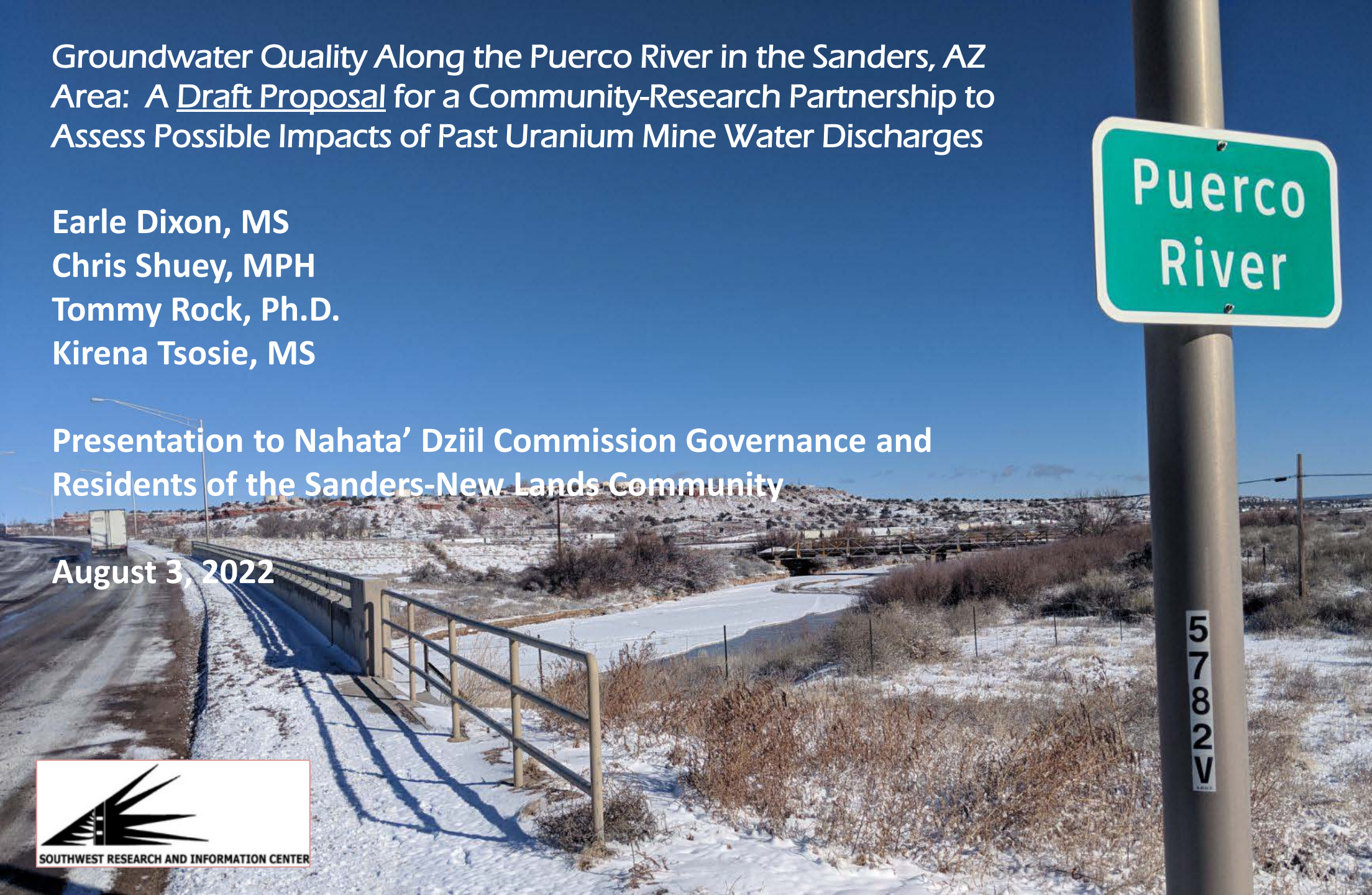
Presentation to Nahata' Dziil Commission Governance and Residents of the Sanders-New Lands Community

August 3, 2022



SOUTHWEST RESEARCH AND INFORMATION CENTER

Funding, Disclosures, Disclaimer, Approvals

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Approvals:

Human research is monitored and approved by UNM Human Research Protections Office (HRPO), the Navajo Nation Human Research Review Board (NNHRRB) and the New Mexico Cancer Care Alliance, as required by federal, state and Tribal law. ***No human research is proposed to be conducted in the study summarized here.***

Our Team

Earle Dixon, MS

- Hydrogeologist-geochemist with 30+ years experience in coal, copper and uranium mining permitting, assessment
- Masters of hydrology, Univ. of Nevada-Las Vegas (1990)
- Work experience: USBLM, Navajo Department of Water Resources; NM Environment Dept.; USEPA Region 6
- Masters' thesis focused on groundwater quality in Puerco River in AZ
- Member of the Eastern Band of Cherokee Indians and a veteran of the US Army.

Chris Shuey, MPH

- 40+ years experience in uranium mining impacts on the Navajo Nation, other tribal communities
- Masters in public health from UNM
- Affiliated with UNM College of Pharmacy on three public health studies of uranium exposures
- Long history of work in Puerco River valley

Tommy Rock, Ph.D.

- From Oljato Chapter, NN
- Studied at ASU, UNM, NAU
- Doctorate in Earth Science and Environmental Sustainability
- Headed water quality study of Sanders area under USEPA grant
- Pursuing post-doctoral work at Princeton Univ.

Kirena Tsosie, MS

- Born and raised in Upper Fruitland Chapter, NN
- BS in marine biology, Univ. of Hawaii; masters in Water Resources, UNM
- Intern for Navajo Department of Water Resources
- Community Water Specialist for SRIC staff member since 2020

Project Summary: Purpose, Objectives

Overall Purpose

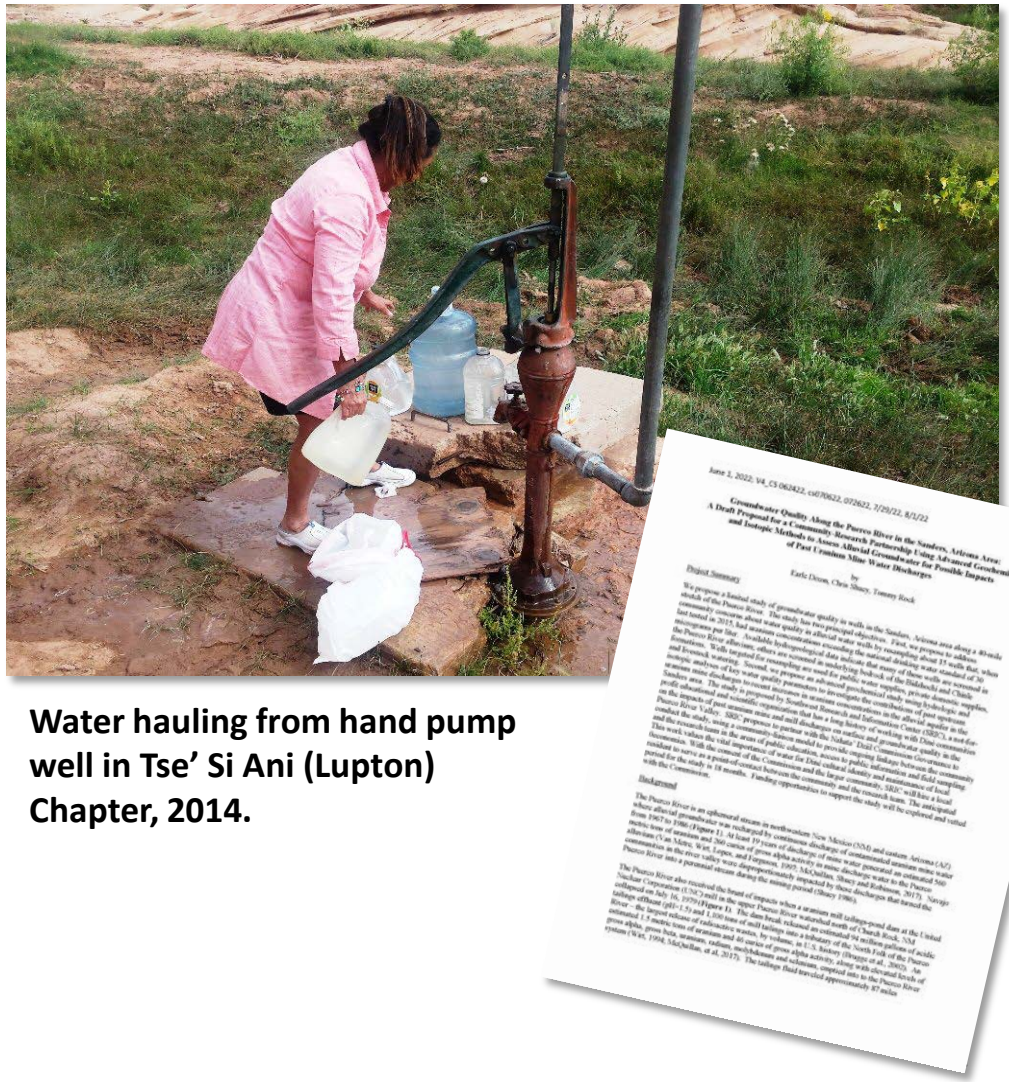
Measure and report on groundwater quality in 15 wells in the Sanders, Arizona area along a 40-mile stretch of the Puerco River.

Two principal objectives:

(1a) Address community concerns by testing water quality in wells that had uranium concentrations >MCL of 30 ug/L in 2015 and before

(1b) Use published data and field recon to ascertain screened internal of target wells to determine if they are alluvial or bedrock

(2) Use hydrologic and isotopic analyses of key water quality parameters to investigate the contributions of past upstream uranium mine discharges

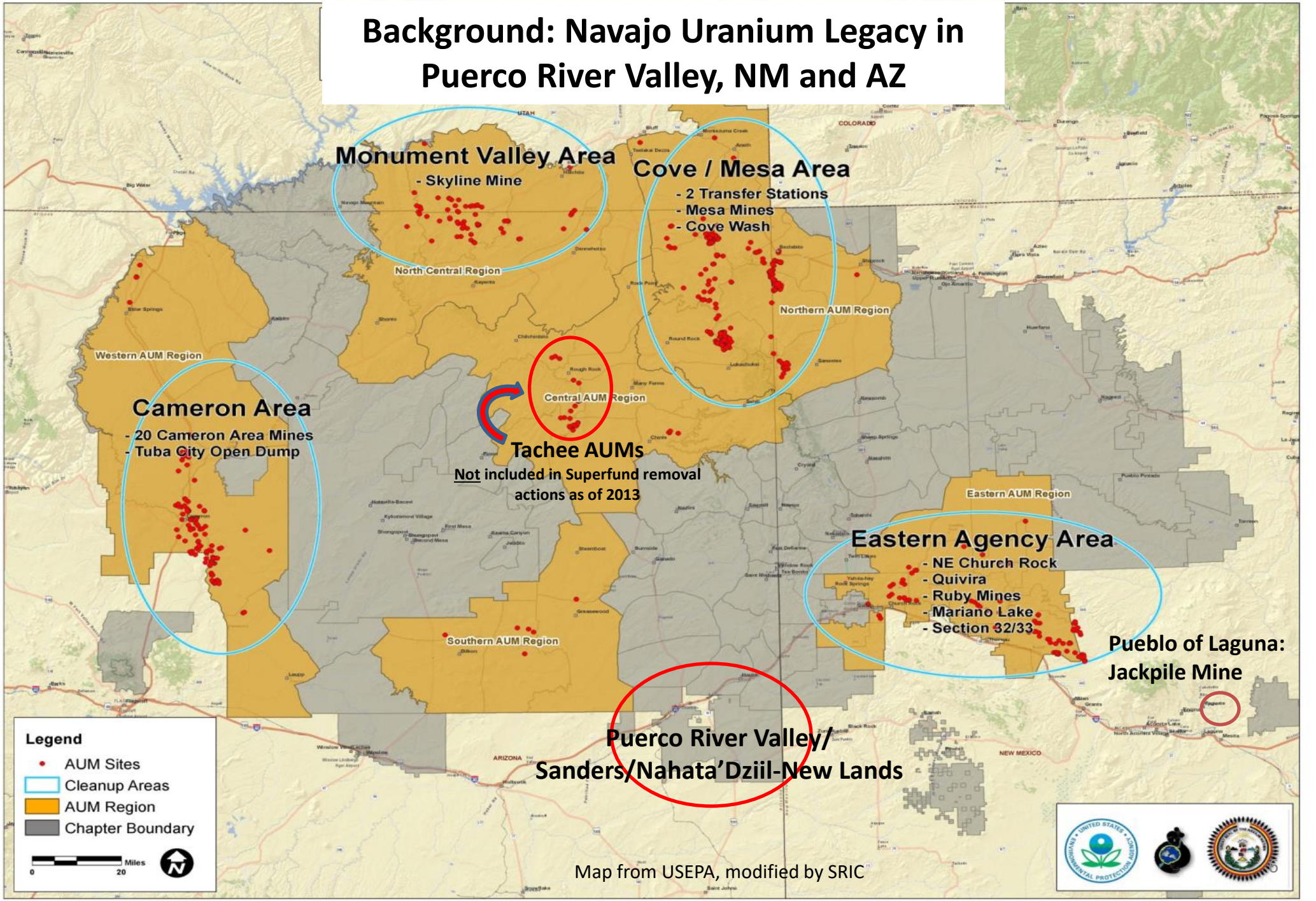


Water hauling from hand pump well in Tse' Si Ani (Lupton) Chapter, 2014.

Project Summary: Administration and Community

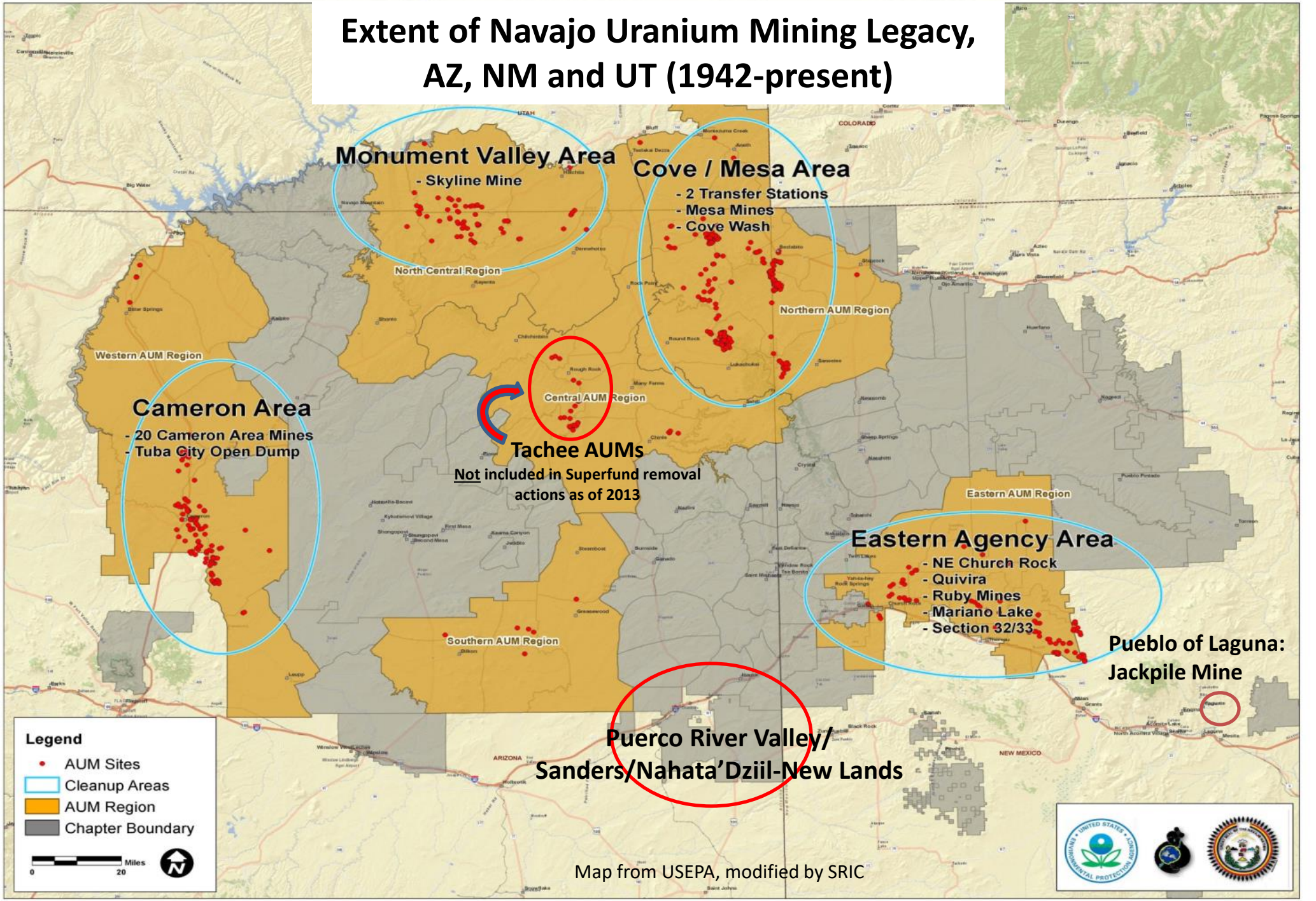
- Proposed by SRIC, a nonprofit organization with a long history of working with Diné communities on uranium impacts on surface, groundwater in the Puerco River Valley
- Partner with the Nahata' Dziil Commission Governance to conduct the study, using community-liaison model to link the community with the research team
- With the consent of NDCG, hire local resident(s) to serve as a point-of-contact between community and research team.
- Value the vital importance of water for Diné cultural identity and maintenance of local economies
- Anticipated period for the study: 18 months.
- Work with Commission to secure funding; preliminary estimated cost = $100K

Background: Navajo Uranium Legacy in Puerco River Valley, NM and AZ



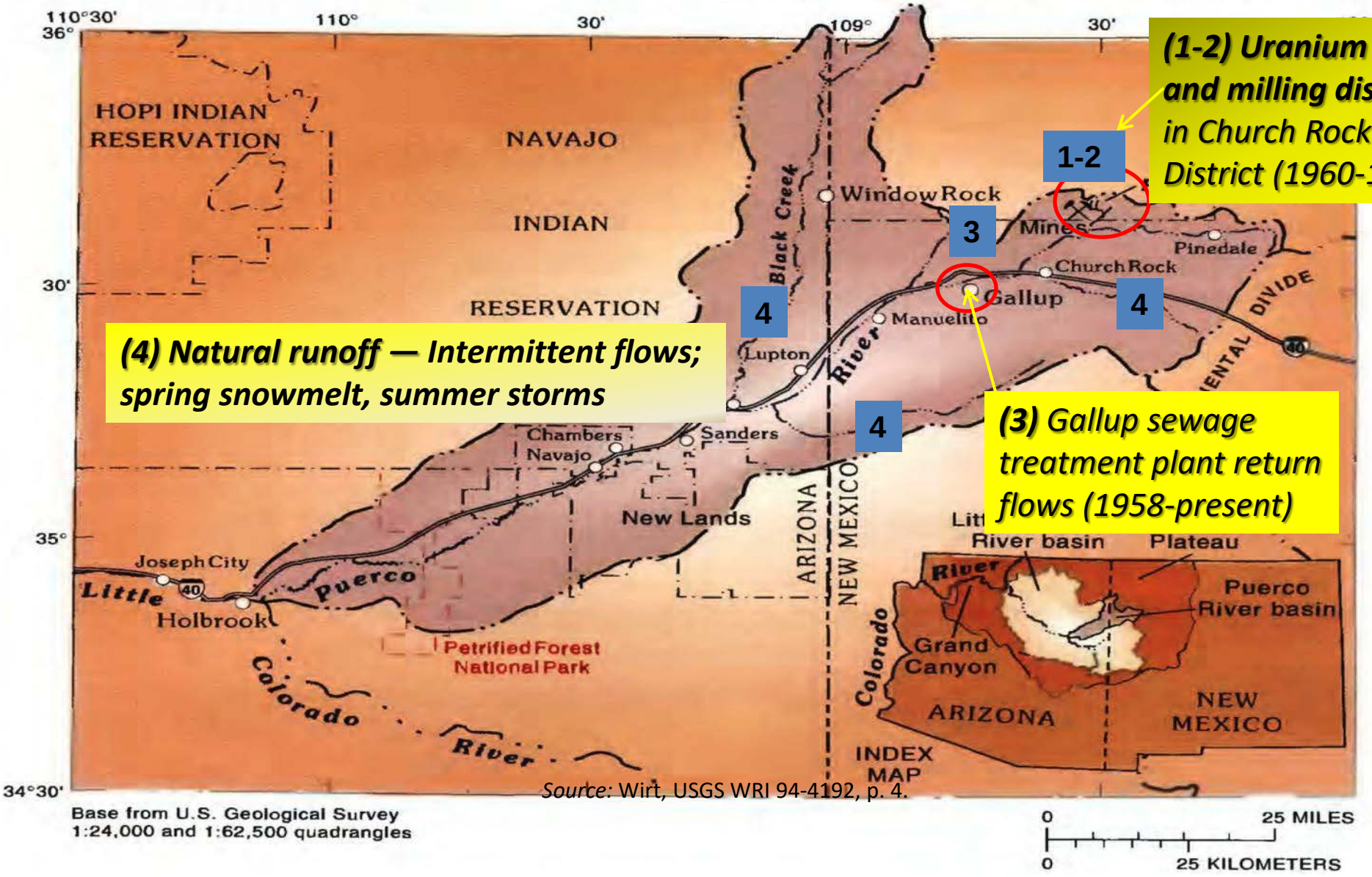
Map from USEPA, modified by SRIC

Extent of Navajo Uranium Mining Legacy, AZ, NM and UT (1942-present)



Map from USEPA, modified by SRIC

Contaminant sources in Puerco River Basin

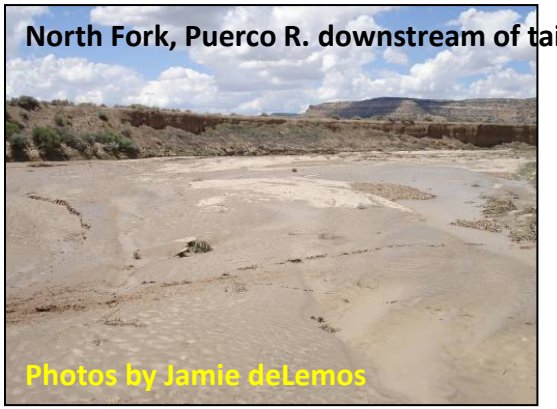


Source: Wirt, USGS WRI 94-4192, p. 4.

Descriptions of Contaminant Sources to Puerco River

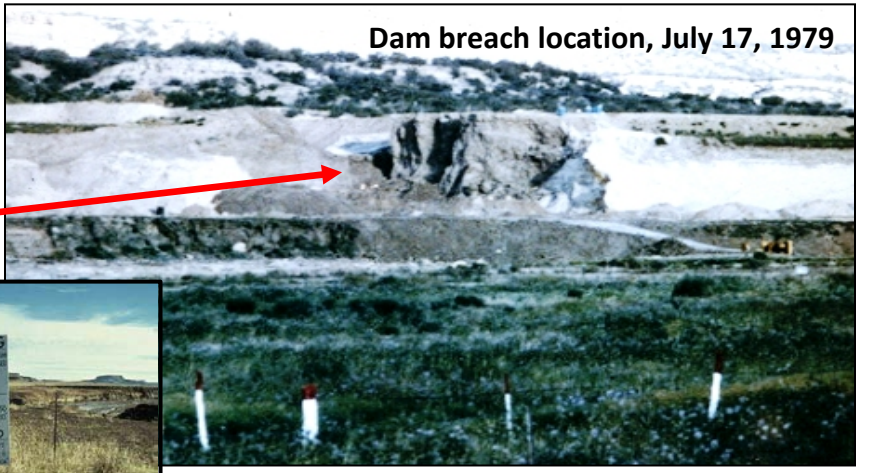
(from deLemos 2008; Shuey, 1992; Van Metre et al., 1997; Wirt 1994)

Source	Description
Church Rock Mill Tailings Spill	▪ One-time "shock" loading on stream; *acidic wastewater* caused burns on feet and legs of livestock and some people
Mine dewatering effluent	▪ 1960-61: ~450 gpm from Old Church Rock Mine ▪ 1977-1983: ave. ~5,200 gpm from 3 underground mines ▪ Continuous dewatering created *perennial flow* in Puerco R
Gallup WTP (1958-present)	▪ 2.4 million gallons treated effluent per day since 1989 ▪ 6.1 million gallon release of raw sewage in 1988
Natural Runoff	▪ Intermittent flows, flash floods from intense storm events (below left) ▪ Increased risk of release of mine wastes to river system (below right)

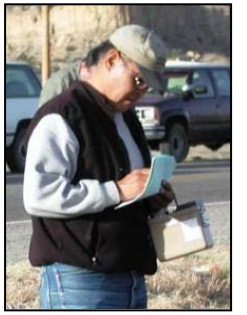


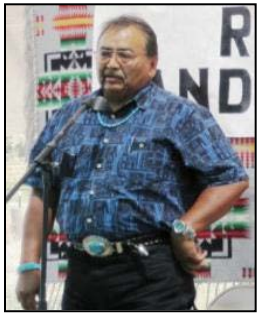
Church Rock Uranium Mill Tailings Spill,* July 16, 1979

*Largest release of radioactive wastes, by volume, in US history;
third internationally behind only Fukushima (2011) and Chernobyl (1986)



UNC crews excavate high-activity sediments from bed of North Fork of Puerco River, October 1979



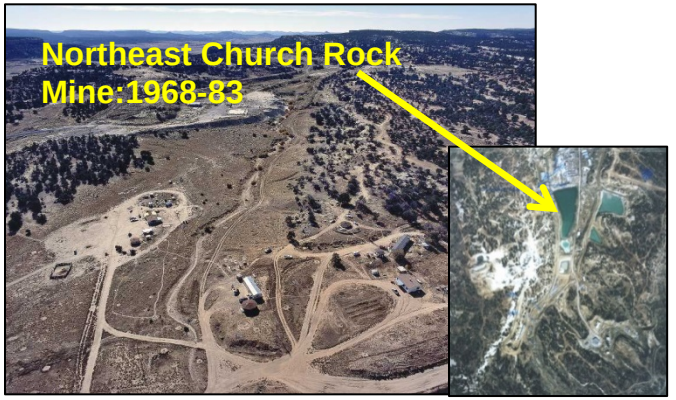


Community leaders Larry J. King (L) and Robinson Kelly addressed long-term impacts of spill in 2009.

Photos courtesy of Southwest Research and Information Center, New Mexico Environmental Improvement Division, Albuquerque Journal, UNM Center for Southwest Research.

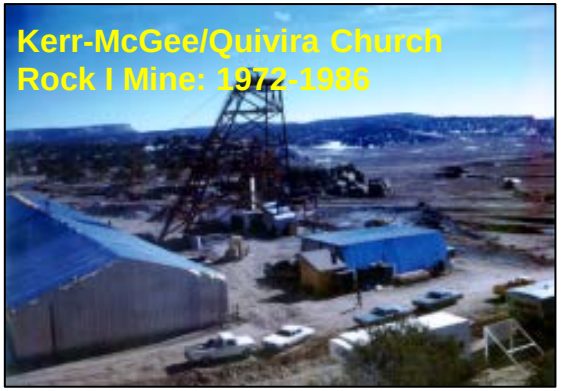
Comparison of Churchrock uranium releases, 1960-1986, to Gold King Mine Release, 2015

Event	Fluid Volume (gals)	pH	Metric Tons Uranium	U (mg/l)	Ra total (pCi/l)	Curies Gross Alpha Activity
Tailings Spill (1979)	94 million	1.4-1.9	1.5 (1,100 tons tailings)	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
Gold King Mine Release (Aug 2015)	3 million	6.0-7.5	Concentrations of radionuclides unknown; estimated 550 tons of metals released (Al, As, Ba, Be, Cd, Co, Cu, Fe, Mn, Ni, Pb, Zn)			

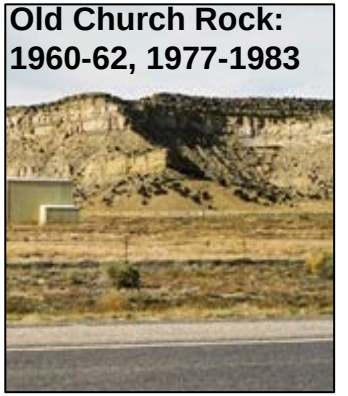


Max discharges: 1,423 gpm ('79) -2,930 ('82)

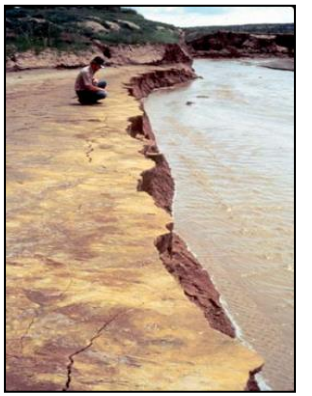
NECR Mine and mine-water ponds ('78)



Max discharges: 3,819 gpm ('80) – 2,819 ('82)



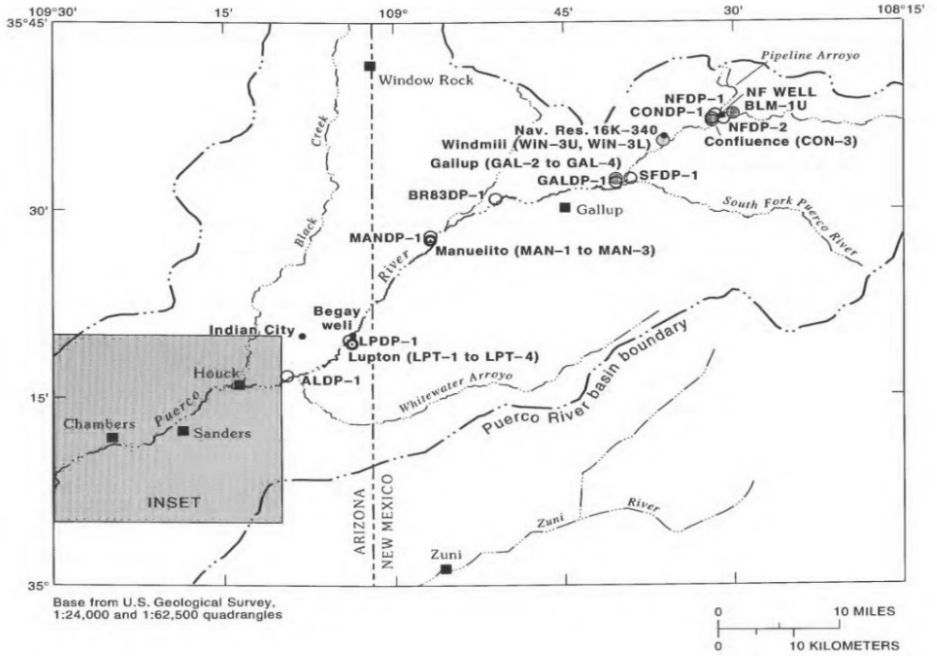
Discharges: 1,189 gpm ('81) – 416 ('82)

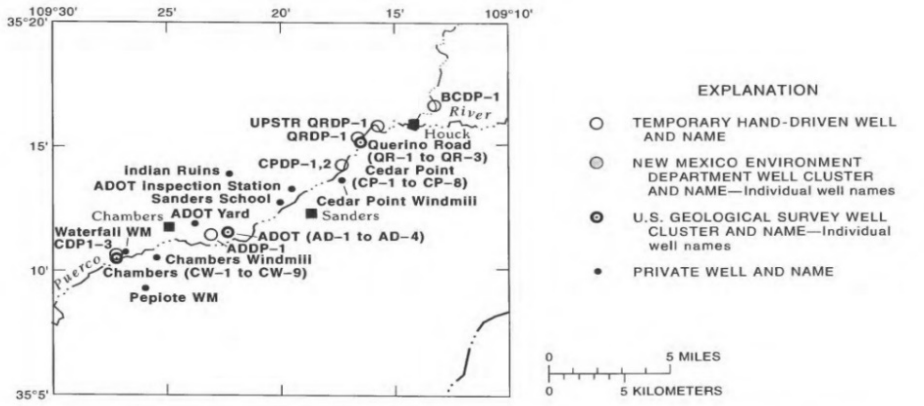


Sample collection near Manuelito, NM 1982

NOTE: Mine water + sewage effluent discharges created perennial flows in Puerco River in NM, AZ between 1969 and 1986. (Data sources: Goad et al., 1980; Shuey and Battista, App. II-B, 2007; USEPA, 1978; Van Metre et al., 1997.)

Water Quality Assessments Over Nearly 50 Years

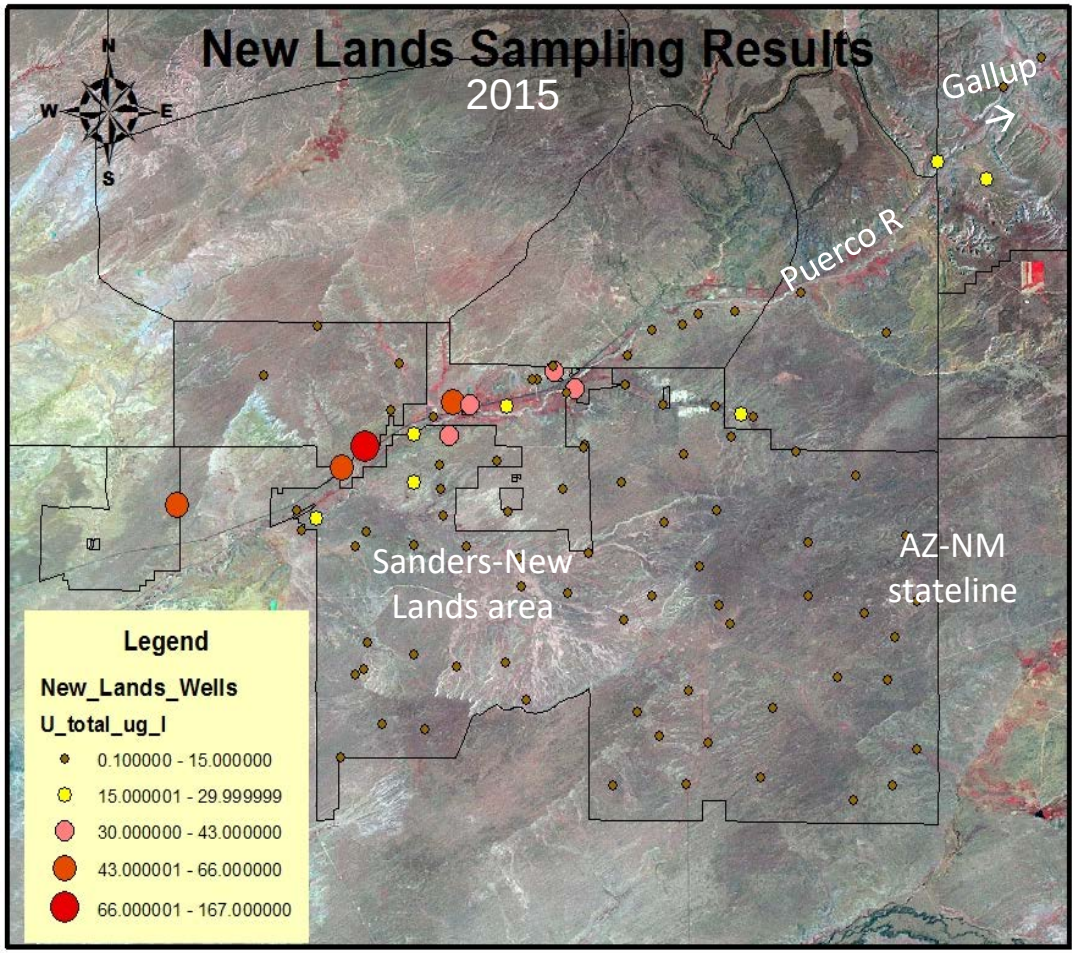




- **1972-1983** — Kerr-McGee Corp./Quivira Mining
- **1972-1984** — United Nuclear Corp.
- **1975-1983, 2003** — NM Environmental Improvement Division/Environment Dept.
- **1979-1985** – Arizona Dept. of Health Services/DEQ
- **1979-1981** — Nuclear Regulatory Commission
- **1983-1988** — U.S. Environmental Protection Agency, Region 9 and Region 6
- **1986-1988** — Southwest Research and Information Center (SRIC) (Puerco River Education Project);
- **1987-1997** — U.S. Geological Survey (under contract to Office of Navajo Hopi Indian Relocation)
- **1989-1990** — Earle Dixon (hydrologist), Master's Thesis
- **2003-2008** — Church Rock Uranium Monitoring Project (CRUMP) (SRIC and Church Rock Chapter)
- **2003-2004** — Navajo Nation EPA
- **2003-2011** — UNM-SRIC Diné Network for Environmental Health (DiNEH) Project
- **2004-2006** — Stanford University-CRUMP (C. George)
- **2006-2008** — Tufts University (J. deLemos)
- **2014-2017** — Tolani Lake Enterprises

Map Source: Van Metre et al., 1997; Figure 6, monitoring stations.

Tółani Lake Enterprises (TLE) sampling in 2015 found uranium-contaminated wells concentrated along the axis of Puerco River in "Sanders Reach"



Map by Tommy Rock

- USEPA environmental justice grant to TLE used to train community members in water quality assessments; SRIC assisted with training, data interpretation
- 190 water sources sampled between Manuelito, NM and Cameron, AZ
- **116 water sources (120+ samples) tested in New Lands-Chambers area**
  - 10.3% had U levels ≥30 µg/l, the USEPA MCL (maximum contaminant level)
  - 5% had U levels between 15-29 ug/l
- Nearly all of wells with elevated U (yellow, orange and red dots) are located along the axis of the Puerco River in the "Sanders Reach"
- Majority of wells completed in alluvium

TLE sampling, 2015

Uranium >MCL found in two alluvial wells providing PWS water to Parks Estates subdivision and the Sanders K-8 School

Park Estates:

- ~70 homes, 250 residents
- Most residents are Navajo
- Community located on private land
- U exposure curtailed when NTUA New Lands water system connected to Park Estates in April 2016

Arizona Windsong Water Co. (AZ0401009)

- Well located ~100' south of Puerco
- Well ~175 ft. deep, completed in *Qal* in 1968 (Dixon, 1990)
- **Abandoned in April 2016**

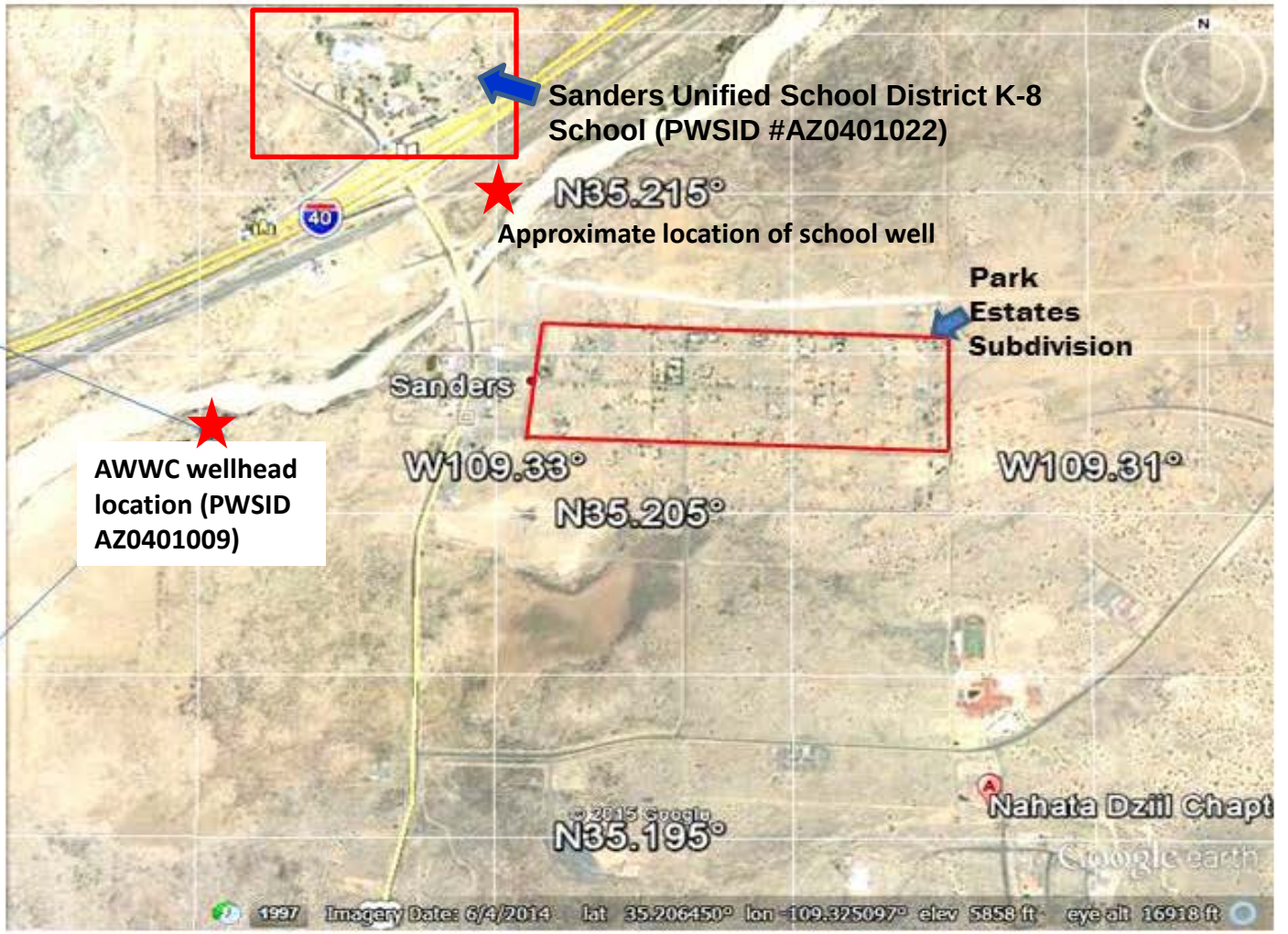
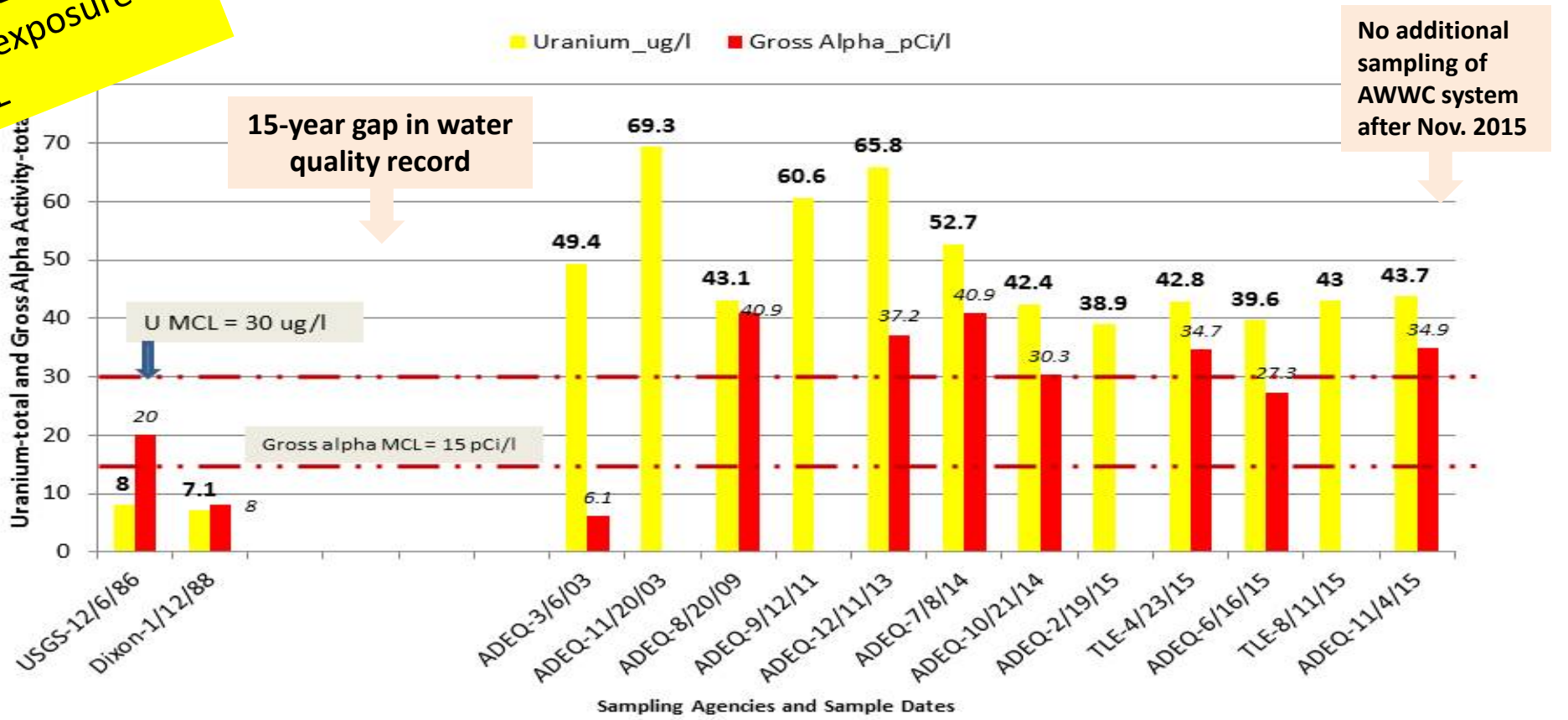


Chart of Uranium and Gross Alpha Particle Activity in AWWC Water System, Sanders AZ

(data* from ADEQ documents and website; TLE Project)

At least 12 years of chronic exposure to U >MCL

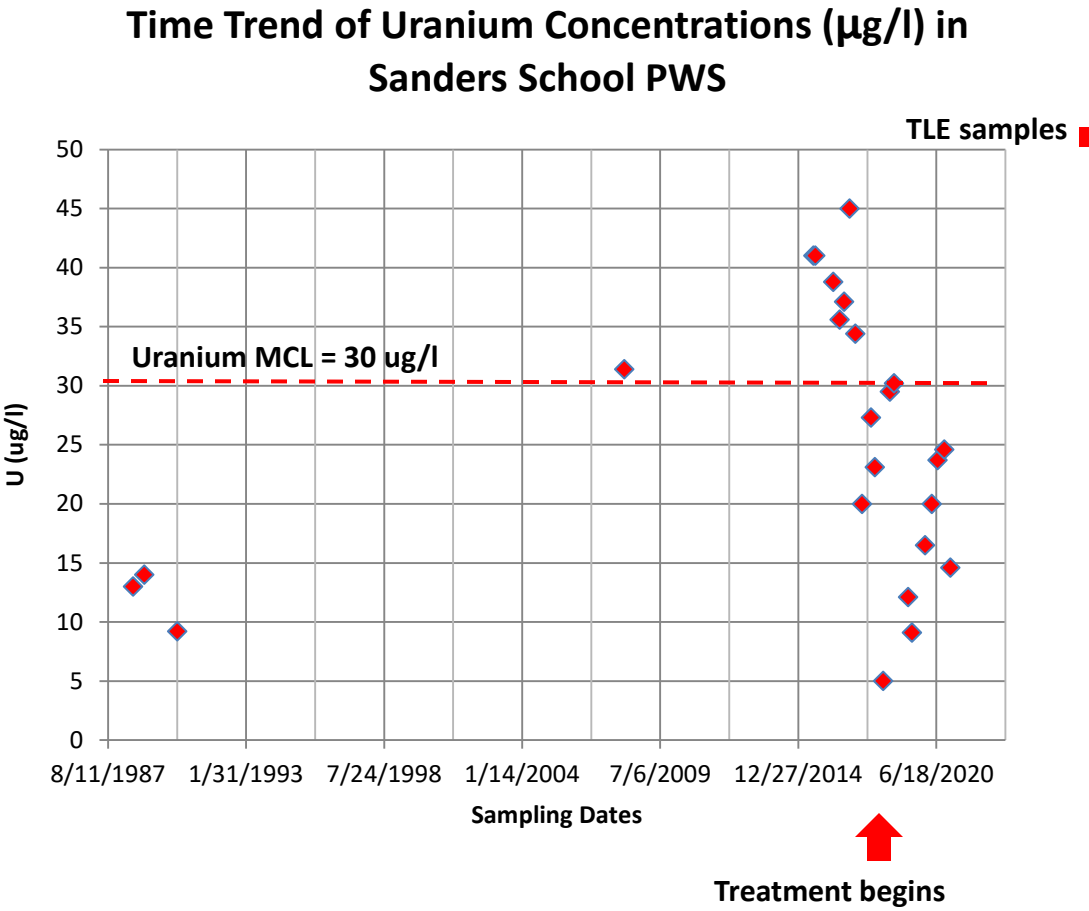


*Compiled by C. Shuey, SRIC, 2015-2016; updated 2/3/16

Sources: *ADEQ 2008-2015 (see, http://azsdwis.azdeq.gov/DWW_EXT/JSP/WaterSystemDetail.jsp?tinwsys_is_number=9&tinwsys_st_code=AZ; Radiochemistry results for samples collected in 2003, converted from pCi/l to ug/l; Public Notice, Aug. 4, 2015; **Tó Łani Enterprises Puerco-LCR Water Quality Project, 2015. ***Webb et al, WRI-87-4126; Dixon, Masters Thesis, 1990. MCL = Maximum Contaminant Level (40 CFR 141).

Sanders School Well completed in alluvial aquifer; U concentrations increased until treatment began in 2017

- Time trend chart suggests U increased in Sanders School Well until treatment applied beginning in 2017-18
- 1988-1990 – 3 samples ranged from 9.2 to 14 µg/l (mean = 12.1)
- 1991-2007 – No data because school well was not considered a regulated public water system
- TLE samples collected from faucet inside school in Aug & Sept 2015 were both 41 µg/l
- Sampling resumed in 2016 after system was reclassified as PWS
- ***9 of 21 samples between 2008 and Jan. 2021 exceeded U-MCL of 30 µg/l***

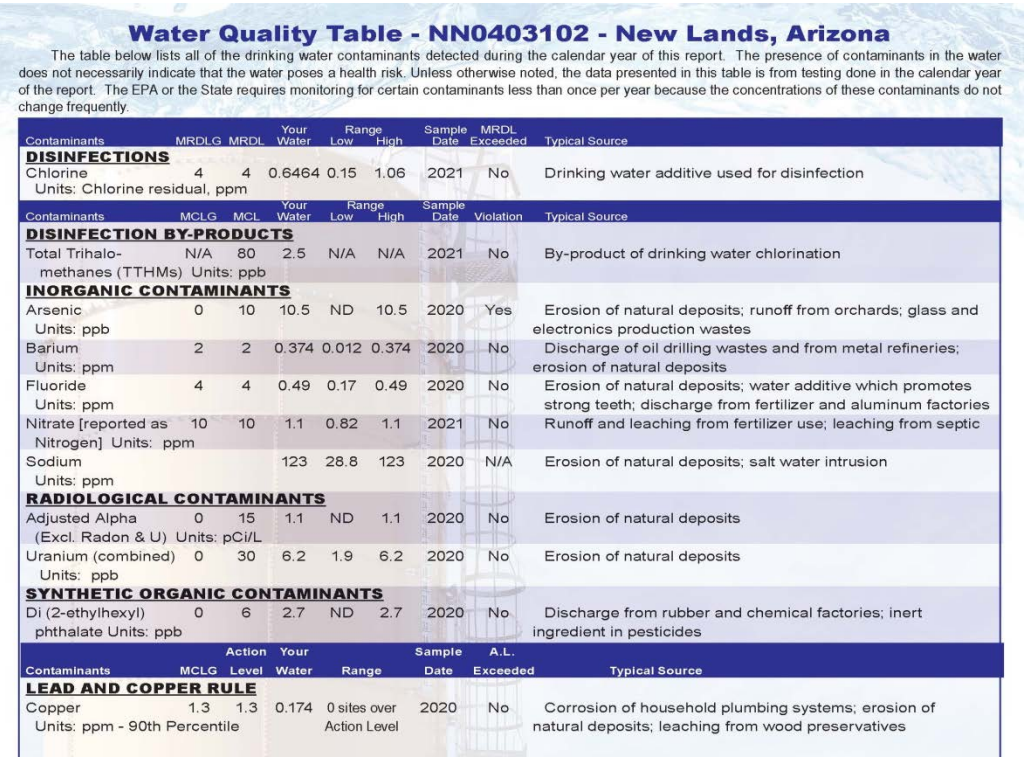


Date	U (µg/l)
8/10/1988	13
1/20/1989	14
5/9/1990	9.2
2/3/2008	31.4
8/5/2015	41
9/2/2015	41
5/17/2016	38.8
8/19/2016	35.6
10/25/2016	37.1
1/10/2017	45
4/4/2017	34.4
7/11/2017	20
11/17/2017	27.3
1/9/2018	23.1
5/11/2018	5
8/17/2018	29.5
10/16/2018	30.2
5/7/2019	12.1
7/1/2019	9.1
1/8/2020	16.5
4/14/2020	20
7/7/2020	23.7
10/13/2020	24.6
1/7/2021	14.6
mean	24.84167
SD	11.63249
median	24.15
N	24

Selected Water Quality Data for New Lands NTUA PWS

https://www.ntua.com/assets/2019ccr_new-lands-nn0403102.pdf

Year	Parameter	MCL (µg/L)	Low (µg/L)	High (µg/L)
2011	Radium (tot.)	5 (pCi/l)		0.4
2011	Uranium	30	1.1	7.4
2013	Arsenic	10		3.0
2017	Arsenic	10		5.9
2017	Lead	15		1.0
2017	Radium (tot.)	5 (pCi/l)		0.9
2017	Uranium	30	1.2	10.5
2019	Arsenic	10		5.3
2019	Lead	15		4
2020	**Arsenic**	**10**		**10.5**
2020	Uranium	30	1.9	6.2



Water Quality Table - NN0403102 - New Lands, Arizona

The table below lists all of the drinking water contaminants detected during the calendar year of this report. The presence of contaminants in the water does not necessarily indicate that the water poses a health risk. Unless otherwise noted, the data presented in this table is from testing done in the calendar year of the report. The EPA or the State requires monitoring for certain contaminants less than once per year because the concentrations of these contaminants do not change frequently.

Contaminants	MRDLG	MRDL	Your Water	Range Low	Range High	Sample Date	MRDL Exceeded	Typical Source
DISINFECTIONS								
Chlorine Units: Chlorine residual, ppm	4	4	0.6464	0.15	1.06	2021	No	Drinking water additive used for disinfection

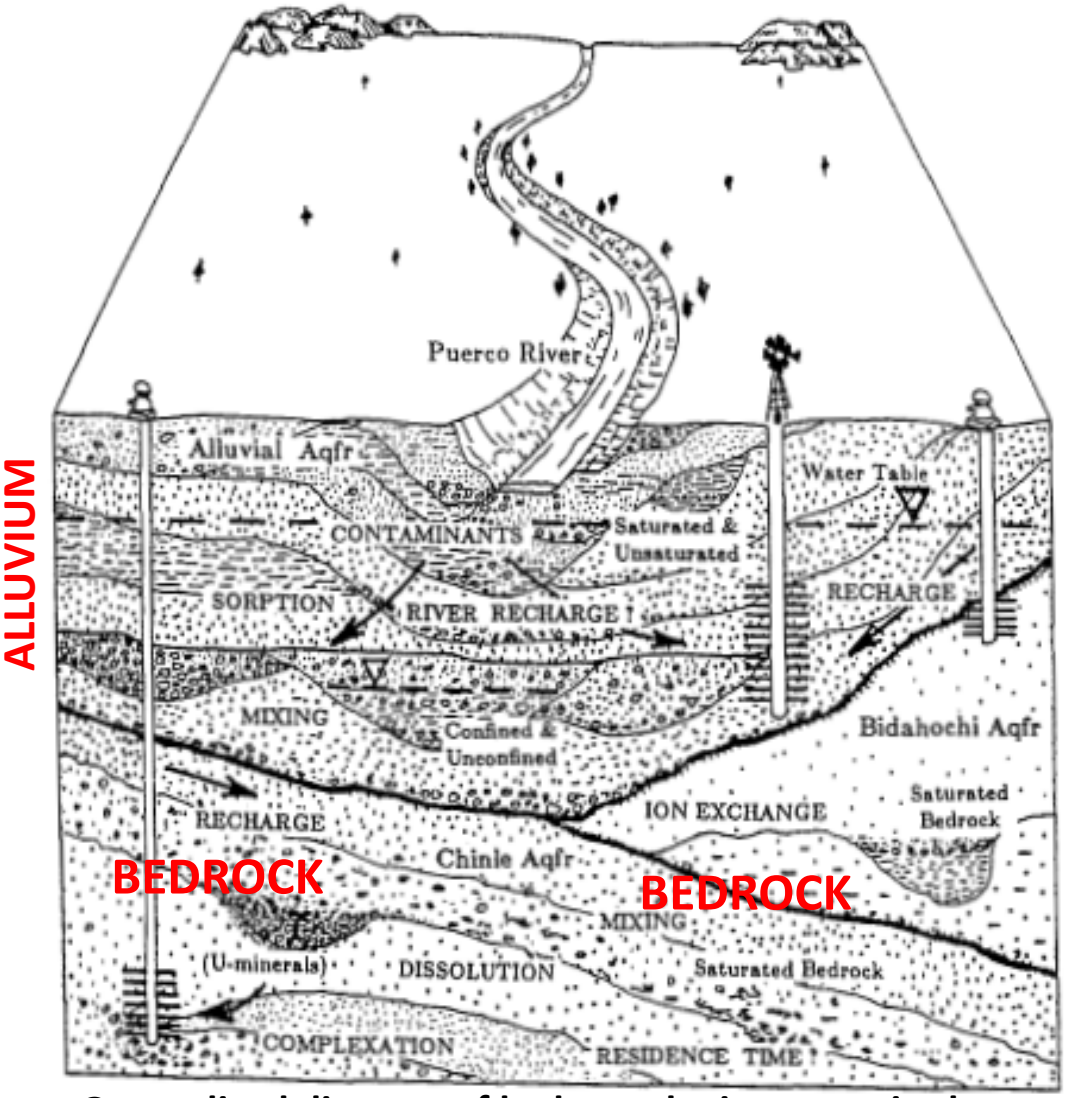
Contaminants	MCLG	MCL	Your Water	Range Low	Range High	Sample Date	Violation	Typical Source
DISINFECTION BY-PRODUCTS								
Total Trihalo-methanes (TTHMs) Units: ppb	N/A	80	2.5	N/A	N/A	2021	No	By-product of drinking water chlorination
INORGANIC CONTAMINANTS								
Arsenic Units: ppb	0	10	10.5	ND	10.5	2020	Yes	Erosion of natural deposits; runoff from orchards; glass and electronics production wastes
Barium Units: ppm	2	2	0.374	0.012	0.374	2020	No	Discharge of oil drilling wastes and from metal refineries; erosion of natural deposits
Fluoride Units: ppm	4	4	0.49	0.17	0.49	2020	No	Erosion of natural deposits; water additive which promotes strong teeth; discharge from fertilizer and aluminum factories
Nitrate [reported as Nitrogen] Units: ppm	10	10	1.1	0.82	1.1	2021	No	Runoff and leaching from fertilizer use; leaching from septic
Sodium Units: ppm			123	28.8	123	2020	N/A	Erosion of natural deposits; salt water intrusion
RADIOLOGICAL CONTAMINANTS								
Adjusted Alpha (Excl. Radon & U) Units: pCi/L	0	15	1.1	ND	1.1	2020	No	Erosion of natural deposits
Uranium (combined) Units: ppb	0	30	6.2	1.9	6.2	2020	No	Erosion of natural deposits
SYNTHETIC ORGANIC CONTAMINANTS								
Di (2-ethylhexyl) phthalate Units: ppb	0	6	2.7	ND	2.7	2020	No	Discharge from rubber and chemical factories; inert ingredient in pesticides

Contaminants	MCLG	Action Level	Your Water	Range	Sample Date	A.L. Exceeded	Typical Source
LEAD AND COPPER RULE							
Copper Units: ppm - 90th Percentile	1.3	1.3	0.174	0 sites over Action Level	2020	No	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives

Note: In the most recent NTUA report (2021), the New Lands PWS exceeded the Arsenic MCL in 2020. This is the first exceedance reported in the past 11 years.

Has uranium migrated into the deepest parts of the Puerco River alluvium over the past 30-40 years?

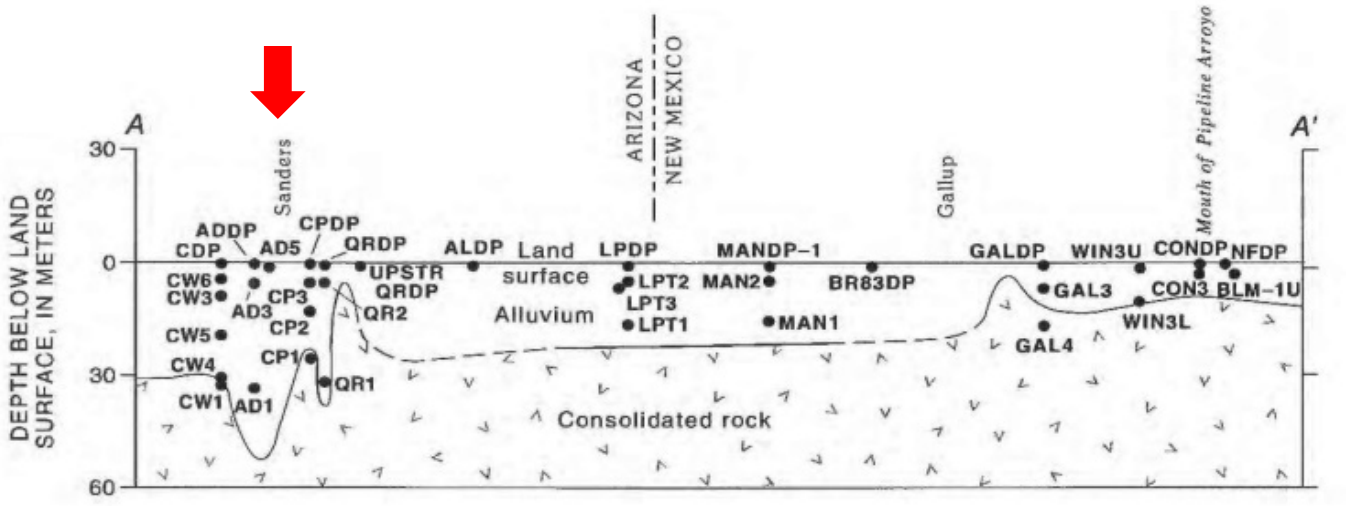
- Puerco River alluvium (*Qal, right*) complex hydrologic system (diagram)
- River water constantly recharging water table in alluvium
- Many wells completed in *Qal* because the water is plentiful, shallow and less costly to develop
- Chemistry of river water affects solubility of uranium, other contaminants
- Is uranium being "released" by changes in chemistry in lower depths of *Qal*?



Generalized diagram of hydrogeologic system in the Puerco River area of AZ-NM (after Webb et al.. 1987b); Dixon, 1990 (Fig. 31).

Several U-contaminated wells, including AWWC and Sanders School wells, are developed in deep *Qal* under Sanders

Cross-section of Puerco River subsurface from Van Metre et al., 1997 (Fig. 16) shows thickening of *Qal* under town of Sanders. AWWC and Sanders School wells are completed near the bottom of the *Qal*. Van Metre et al. found that "tritium activities indicate that recharge from runoff and precipitation has moved to the lower parts of the alluvial aquifer since about 1952" (p. 31). Low radium-226 concentrations in 2015 TLE samples consistent with Dixon's (1990) finding that "sparse" ^{226}Ra not as easily mobilized as the U ion.



- **AWWC well ~175 feet in total depth (~54 meters)**
  - 7-8 ppb U in 1986-88 (Dixon, 1990)
  - 39.6 – 69.3 ppb U from 2003 to 2015 (ADEQ, TLE)
  - Location not shown on Fig. 10 (above) from Van Metre et al., 1997 because the AWWC well was not included in the study
- **Sanders School well ~160 feet deep (~49 meters)**
  - School well used as sentinel well after tailings spill; showed spikes in gross alpha radioactivity
  - 31.4 µg/l U in December 2008 (ADEQ data)
  - 37-41 ppb U in 4 samples in 2015 and 2016

Proposed Research Plan, Objective 1

Objective 1 – Water quality surveillance, assessment

(1a) Address community concerns by testing water quality in wells that had uranium levels >MCL of 30 µg/L in 2015 or before

- Obtain community input into the list of wells to be resampled
- Resample and test at least 12 wells for major ions (7), uranium and other metals (22), radionuclides (4)
- Prioritize wells used for drinking water, domestic purposes, livestock watering
- Select 2-3 alluvial wells with U ≤15 µg/L to provide geochemical data for comparison with data from U-contaminated wells

(1b) Use published data and field reconnaissance to ascertain screened interval of target wells to determine if they are alluvium or bedrock

- Review, evaluate well completion records to confirm or revise data on producing formations (alluvium v. Bidahochi or Chinle formations)
- Correlate U, metals concentrations with hydrogeological and geochemical data

List of Proposed Analytes

- **Field parameters:** Electrical conductivity (EC); pH; temperature; dissolved oxygen (DO); oxidation- reduction potential (ORP or Eh), field bicarbonate (HCO_3)
- **General Chemistry/Major Ions:** TDS, Ca, Mg, K, CO_3, HCO_3, SO_4, Cl, NO_2, NO_3, F
- **Metals:** Al, Sb, Ba, Be, Cd, Cr, Co, Cu, Fe, Hg, Mn, Ni, Pb, Ag, Se, Tl, U (mass), V, Zn
- **Radionuclides:** Gross alpha activity, U-238, -235, -234, radium-226 & -228, gross beta activity
- **Isotopes for geochemical analyses:** S-34, O-18, H-2 (deuterium)

Note: Hydrogen isotopes were used in previous USGS studies of Puerco River water quality (1997)

Preliminary List of Wells to be Sampled, Tested

Well Name	TLE #	Use(s)	DD Lat	DD Long	TD (ft)	Producing Formation	U > MCL in past?
18-4-5 (handpump)	N002	L, D	35.22616	-109.34157	<20	Alluvium	No
18K-307	N015	L	35.23330	-109.28443		Alluvium	No
Private well (AL)	N076	D	35.22186	-109.34070			Yes
ATSF-3 (Chambers #65 at gas station)	N073	D	35.19036	-109.43351		Alluvium	Yes
AWWC PWS (abandoned)	N001	PWS	35.207741	-109.336454	175	Alluvium	Yes
Chambers #8 (capped)	N004	L	35.17764	-109.42115		Alluvium	Yes
Highway Well #47	N090		35.15449	-109.50406			Yes
Highway Well #64	N091	L	35.08339	-109.67786		Alluvium?	Yes
Private well (LJ)	N088	L, D	35.16962	-109.4864		Alluvium?	Yes
Private Well (SN)	N0116	D				Alluvium?	Yes
ONHIR Well	N0104	D	35.19893	-109.40567			Yes
Private Well (RL)	N082	D	35.20052	-109.41882			Yes
Sanders Unified School District	N015	PWS	35.215786	-109.328679	160	Alluvium	Yes
Sandhill Well (aka, Pinta Well at Padres Mesa Demo Ranch)	N092	L	35.12818	-109.63082		Alluvium?	No
TBD						Bidahochi Fm.	
TBD						Chinle Fm.	
TBD						Alluvium (where U ≤15 µg/L)	

We will define each well by its land-ownership jurisdiction; not all of these wells are Navajo Nation-owned

Proposed Research Plan, Objective 2

Objective 2 – Geochemical, isotopic analyses

(2) Use hydrologic and isotopic analyses of key water quality parameters to investigate the contributions of past upstream uranium mine discharges

- Evaluate hypothesis that past uranium-mine water discharges contributed to current elevated U levels in alluvial wells in the Sanders area
- Apply geochemical strategy used in San Mateo Creek Basin (NM) to Puerco River hydrologic system in "Sanders Reach"
- Use isotopic data for sulfur (S-34), oxygen (O-18), hydrogen (H-2) to age-date alluvial groundwater, examine sulfur isotopic ratios to track or trace the presence (or absence) of uranium mine discharge water that has recharged alluvial groundwater in the Sanders area
  - U ores in Western U.S. depleted in the heavier sulfur isotope (S-34), as shown in graphic at right from Jensen, 1963
- Characterize water quality in selected bedrock wells for comparison to alluvial water quality
- Report findings, make recommendations

Geochemical indicator: depletion of heavier isotope of sulfur (S-34) in western uranium ores

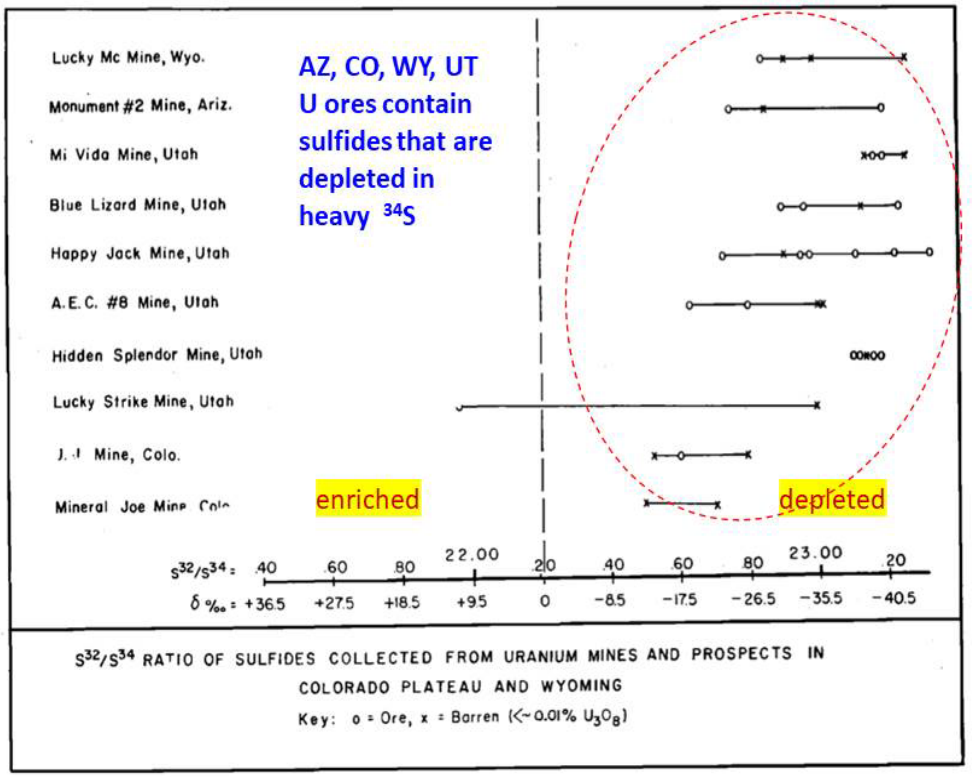


FIG. 3. S^{32}/S^{34} ratio values and permil values of sulfides collected from uranium deposits of the Colorado Plateau and Wyoming. O = Ore, X = Barren (< ~0.01% U_3O_8).

Staffing and Budget

Community Engagement, Staffing

- 1 community liaison (0.5 FTE)
  - Would be hired by SRIC with community input
- 4 scientists (0.2 FTE each)
- Regular communication with community leaders, members
- Explore partnerships with UNM METALS Superfund Research Center, other universities
- Request resolution of support from Nahata' Dziil Commission
- Explore funding opportunities
- During study period, work with community to explore options for assessing human exposures to contaminated water sources

Preliminary budget, likely will change

Category	Detail		Totals
Salaries & Benefits	Geochemist (0.2 FTE)	E. Dixon	$40,000
	Environmental health scientist(0.2 FTE)	C. Shuey	
	Environmental scientist (0.2 FTE)	T. Rock	
	Water Management Specialist (0.2 FTE)	K. Tsosie	
	Community liaison (0.5 FTE)	TBD	
Travel			$5,000
Supplies			$2,500
Laboratory Costs	15 samples x $2,500 each		$37,500
Equipment	Dissolved oxygen meter	$100-$300	$15,000
	Geopump for filtration		
	Portable water level meter		
	Oakton or YSI multi-purpose field meter (pH, temp, conductivity, salinity/TDS	~$2,500	
TOTAL BUDGET	Preliminary estimate only		$100,000

Questions, Comments?

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Photo of Entrada Cliffs @ Lupton by L. Blalock