Multigenerational Legacy of Uranium Mining on the Navajo Nation

A community/research/tribal and federal agency partnership to determine the relationship between uranium exposure, birth outcomes, and development on the Navajo Nation

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NM CARES Health Disparities Center
Expanding Scientific Knowledge

Environmental Health Core

With acknowledgement and thanks to the NBCS Team!

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And thank you to the many others who have contributed and supported this work!

The people of the Navajo Nation:

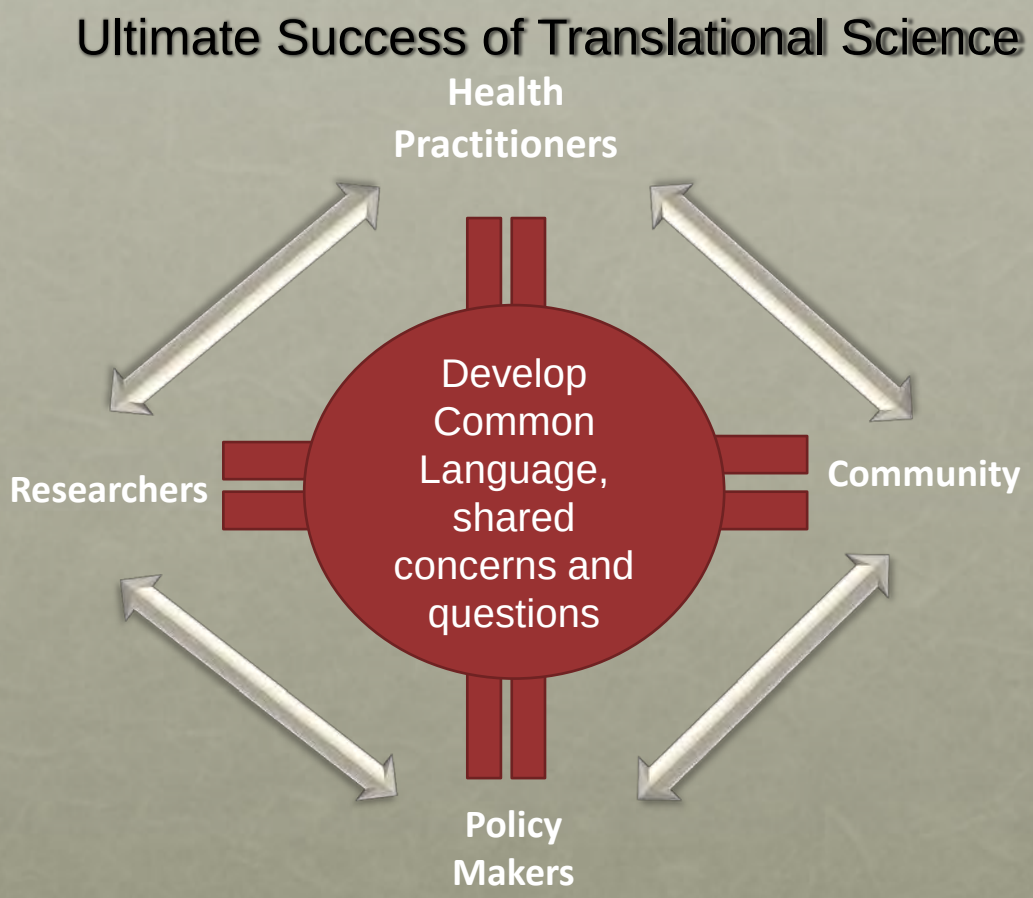
- 2000 Navajo families
- 110 chapters
- HEHSC, Tribal and Agency Councils, Executive Branch, NNEPA, GIB

Our funders:

- NIEHS (16 yrs)
- CDC/ATSDR (5 yrs)
- USEPA Region 9 Superfund Emergency Response (4yrs)
- NIMHHD (3 yrs)
- NNEPA (1 yr)
- NIAAA (2 yrs)

DiNEH and NBCS Research is reviewed and monitored by Navajo Nation Human Research Review Board

CEHP Research Model Since 1996



Iterative approach – follow the questions

Why the Navajo Birth Cohort Study?

How should the research be conducted?

Background

The PROBLEM

- **More than 40 years of Cold War mining on Navajo Nation**
  - > 500 abandoned, unmarked, unfenced mines left
  - > 1000 individual waste sites – all metal mixtures, all unremediated


Los Angeles Times
latimes.com
Go 7:55 AM PST, November 19, 2006
Blighted Homeland
(Gail Fisher / LAT)
They took shelter amid the poison
During the Cold War, uranium mines littered the Navajo Nation with contaminated waste. People developed cancer. And the U.S. did little to help.
Gov.'
may
Schwarze
covering
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Tunnels
The subter
chaos alon
U.S. has
Shift power
Choices re
MORE NE

- **Communities Concerned about effects → Congress, UN**
  - Concerned about Now and for *future generations*
  - Distrust research due to prior history of disrespect, abuse, secrecy

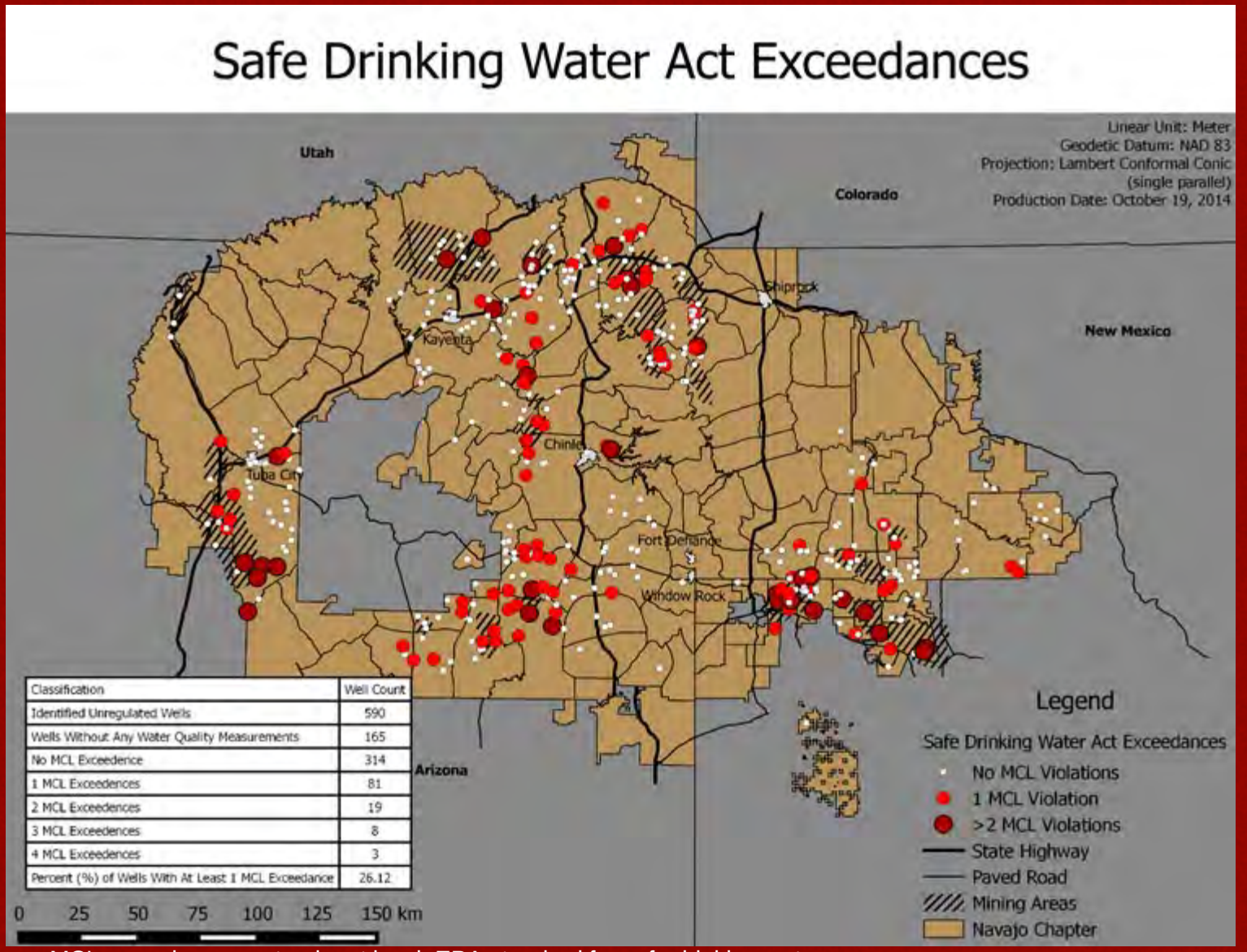
- **Highest percentage of tribal populations localized to 13 western states**
  - Highest concentration of abandoned uranium mines (>4000), as well as other hard-rock mines (>161,000) localized to same region

Health Risks to Tribal Populations

- **Little understanding of health risks in these populations**
  - Generally not accessible as a group in national datasets
  - Limited tribal-specific data, only proportional (~2%) representation (if any)
- **Differ in exposure pathways**
  - Differ in Land, Water, Resource Use Patterns, lower mobility
  - More subsistence lifestyles – greater reliance on locally grown foods → increased exposure risk
- **Many SES factors linked to health disparities**
  - Low income levels (household <$20K median)
  - High unemployment (e.g. >40% Navajo, >75% Sioux)
  - Poor infrastructue (>30% lack access to regulated water)

Water-borne toxicants:

Inorganic Metals for 427/702 unregulated wells: DiNEH Project, USACE, USEPA, USGS, CRUMP, CDC/NNEPA



Sampling bias in regions of known mining

DiNEH project sampled all wells used by participants for drinking in 20 chapters

Arsenic (~15%) and uranium (~13%) account account for the majority of water sources (26%) exceeding the established MCL.

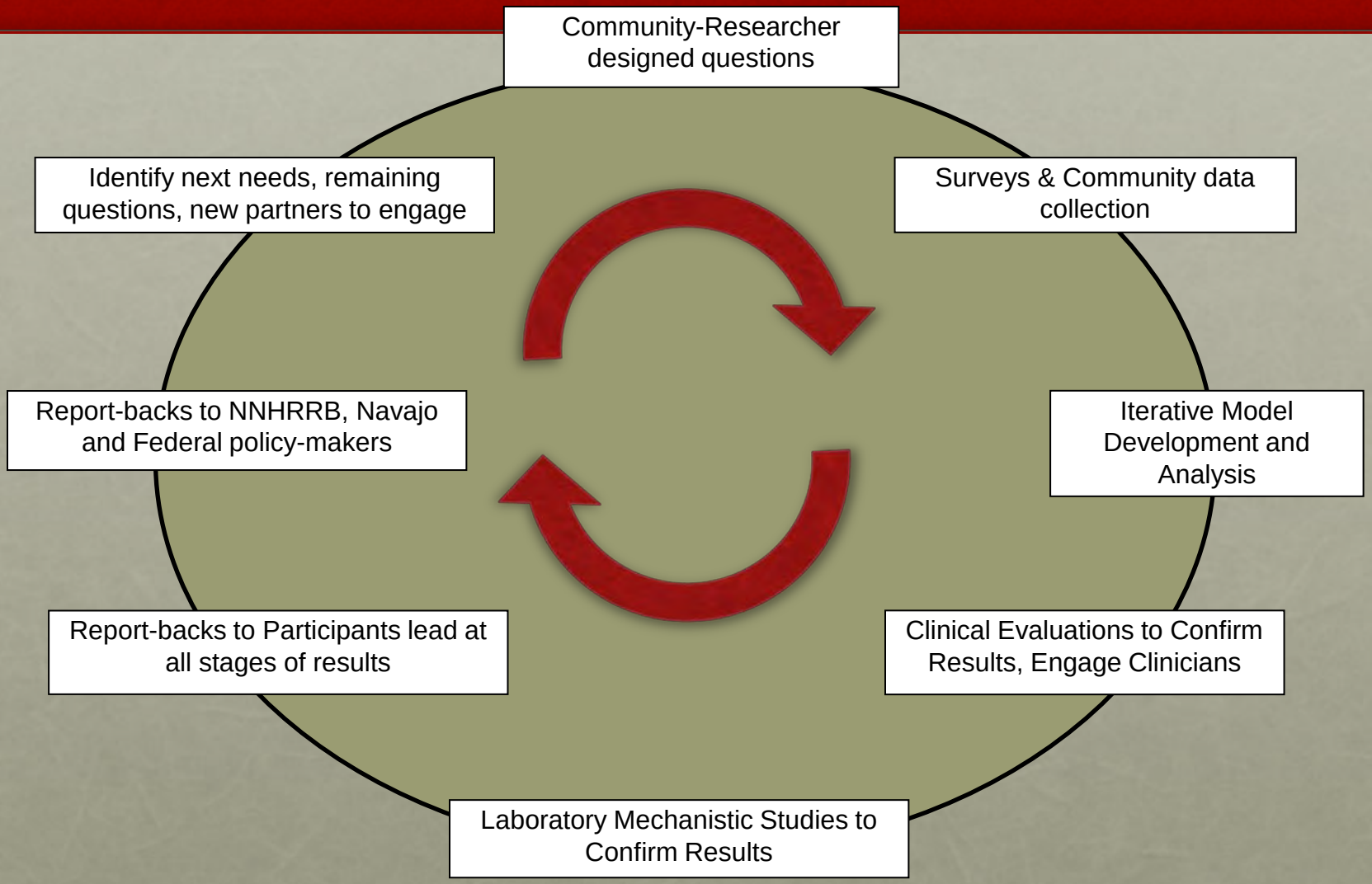
MCL = maximum contaminant level, EPA standard for safe drinking water

Reproductive and developmental concerns – tribal populations

- **50% higher prevalence for 8 tracked birth defects (Canfield et al., 2014)**
  - Doesn't count states with highest % tribal populations – small tribal *n*
  - No assessment of environmental risk factors
- **AI/AN historically higher rates of**
  - preterm birth,
  - low (and high) birthweight,
  - miscarriage,
  - stillbirth,
  - infant death
  - hypertensive disorders,
  - preeclampsia,
  - gestational diabetes
- **Generally not represented in existing prevalence or toxicity studies**
  - no comprehensive data on birth defects, autism, developmental delays – or culturally specific developmental norms

Combined Iterative Model

Research Approach Mirrors Navajo Learning method
Basis for original DiNEH Project and current Navajo Birth Cohort Study



Synthesized Research Model for DiNEH Project and Navajo Birth Cohort Study

DiNEH Project Results:

Active-mining era exposures (workers and family) increased risk of kidney disease

Active-mining related exposures were estimated from self-reported survey data

A: Washed the clothes of a uranium worker (22%)
B: Worked in a uranium mine (10%)*
C: Lived in a mining camp (4%)
D: Worked in a uranium mill (2%)*
E: Worked on a uranium mine or mill reclamation or hauled uranium ore or tailings in a pickup truck (2%)

**Many workers have already died from lung cancer, cohort had more family members than workers*

Hund et al., 2015, Journal of Royal Statistical Society, Series A, Statistics in Society

DiNEH Results:

Ongoing environmental legacy exposures → increased risk for hypertension, autoimmune disease; developing one and more chronic diseases

Exposures include the following activities:

A: Used materials from abandoned uranium mine or mill (17%)

B: Herded livestock next to uranium mine, mill or waste dump (13%)

C: Drunk or contacted uranium mine waste water (13%)

D: Played on a uranium tailings pile or waste dump (13%)

E: Played outdoors near a uranium mine, mill, or waste dump (12%)

F: Sheltered livestock in an abandoned uranium mine (2%)

**Note: Median length of residence in current homes was 33 years*
Also a relationship with living near mines (up to 25% do not know).

Hund et al., 2015, Journal of Royal Statistical Society, Series A, Statistics in Society

Navajo Birth Cohort Study
2010-2017 – Congressional Mandate
Cooperating Organizations

Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry

DiNEH Project Team

- UNM Community Environmental Health Program (CEHP)
- UNM Pediatrics Department, Center for Development and Disability
- Southwest Research and Information Center (SRIC)
- Consultants

Birth Cohort

Navajo mothers, fathers and babies; other community members; chapters

Navajo Area Indian Health Service (NAIHS)

Navajo Nation Department of Health

With Help From

- Growing in Beauty (developmental disabilities services provider)
- PL93-638 Facilities (Tséhootsooí, Tuba City)
- Other Navajo Nation Agencies (Environmental Protection Agency. WIC, Health Education, Office of Uranium Workers)
- USEPA Region 9

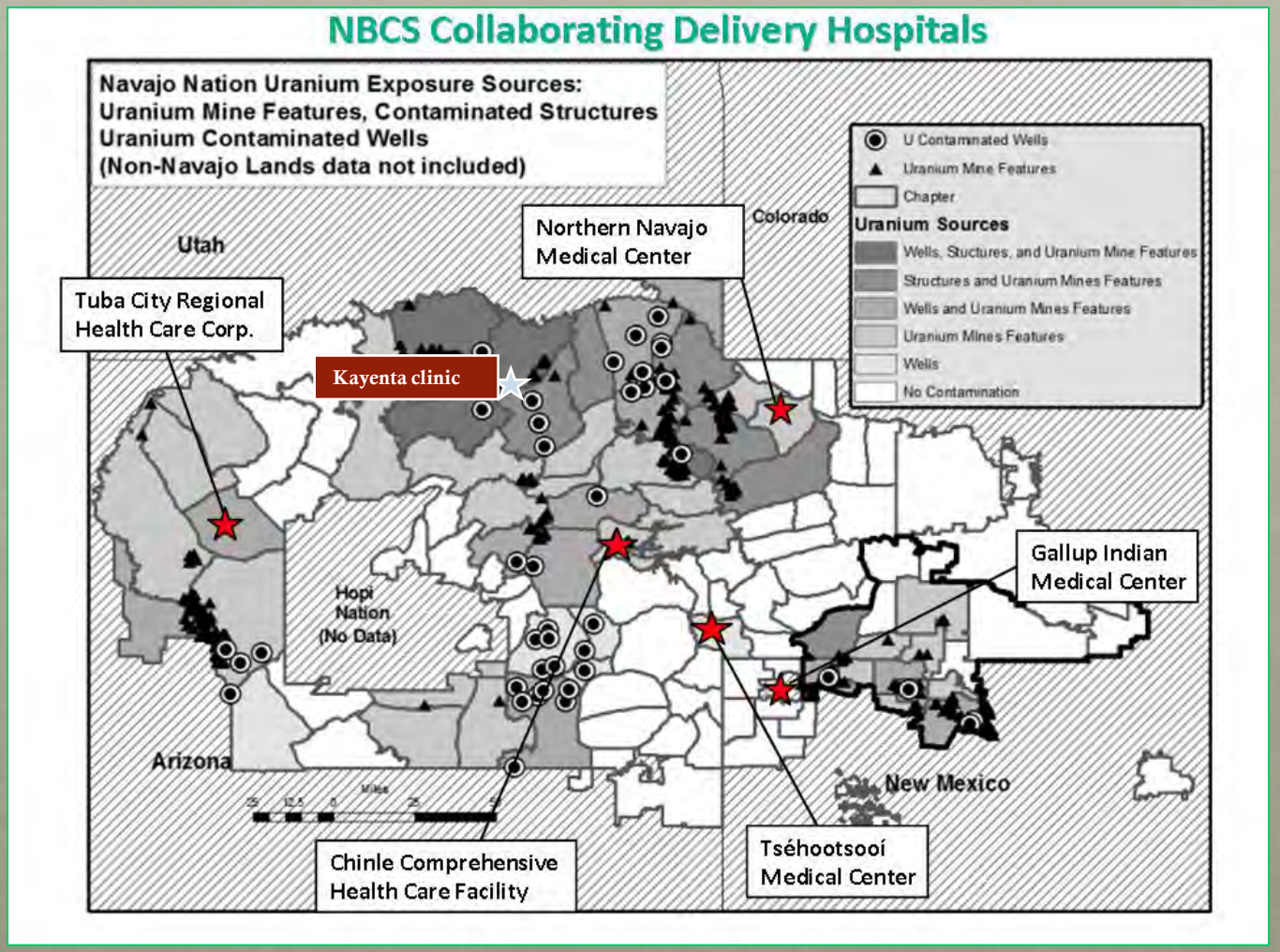
Body of work will result in data on three successive generations

- **Separate exposures during active mining from those to legacy waste**
- **Extensive exposure characterization:**
  - biomonitoring, home assessment, self-reported exposure, environmental monitoring
- **Clinical and developmental assessments**
- **Laboratory mechanistic studies**
- **Understanding of Exposure Pathways:**
  - Investigation of minerologic, physico/geochemical properties of waste affecting exposure & disease
- **Research to understand risk, inform regulatory action, prevention strategies**

Building the cohort

NBCS Birthing Hospitals in Relation to Principal Uranium Exposure Sources

Navajo Area OB/GYN Birth Statistics (2009) Self-Reported at Area and National Meetings (Source: NAIHS clinical staff)	
Chinle	541
Tséhootsooí (638)	459
Gallup	664
Shiprock	763
Tuba City (638)	519
Total	2,946



Note: Kayenta clinic designated by NAIHS as NBCS prenatal care facility; began enrollment October 2014, no deliveries

Outcomes Model Structure

EXPOSURE INPUTS

Uranium
Proximity, dust, occupation, water, land use
Survey, GPS, NURE data, Biomonitoring, Existing water quality, in-home dust, parent biomarker analyses

Radiation
Home scans
Biomonitoring, Existing data

Radon
In-home
Canister monitoring

MODIFIERS

Reproductive History
Mother and father
Survey & Medical Records

Nutritional Status
Mother
WIC, FFQ, Biomonitoring

Demographic Variables
Parental income, education, parental ages
Survey

Alcohol, Substance Abuse
Surveys, Meconium, Medical Record

Co-Exposures
Other metals, PAHs, Particulates, Sulfur Compounds
Biomonitoring, Surveys, Home Assessments

REPRODUCTIVE OUTCOMES

Reproductive Difficulty
Miscarriage, delivery complications
Medical Record

Low Birth Weight
Medical Record Review

Congenital Malformation
Medical Record, Survey

DEVELOPMENTAL OUTCOMES

Development: Behavior
communication, gross & fine motor skills, problem solving and personal social skills
ASQ-I & Mullen

Development: Physical
Length, weight, head circumference
Anthropometry

Development: Medical
Infections, Morbidity, Mortality
Medical Record Review

Development: Biomarker
Inflammation, Immune system
Laboratory Analysis

Characterizing the cohort

Biomonitoring

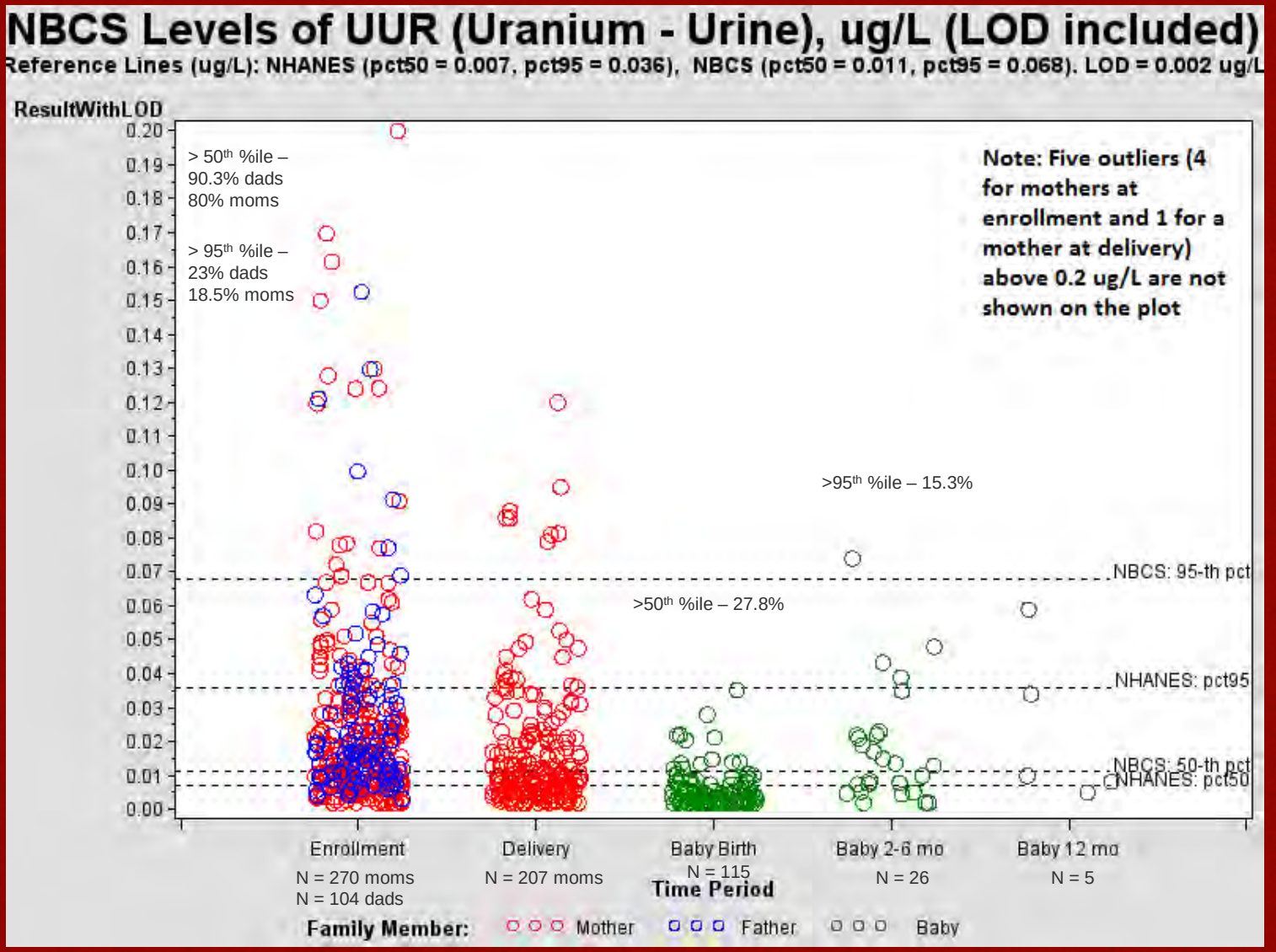
Home Environmental Assessments

Environmental Monitoring

Biomonitoring in the NBCS

- Multiple time points and biological media
- CDC laboratory testing for 36 different metals/metalloids of interest including **arsenic, uranium, lead and mercury**

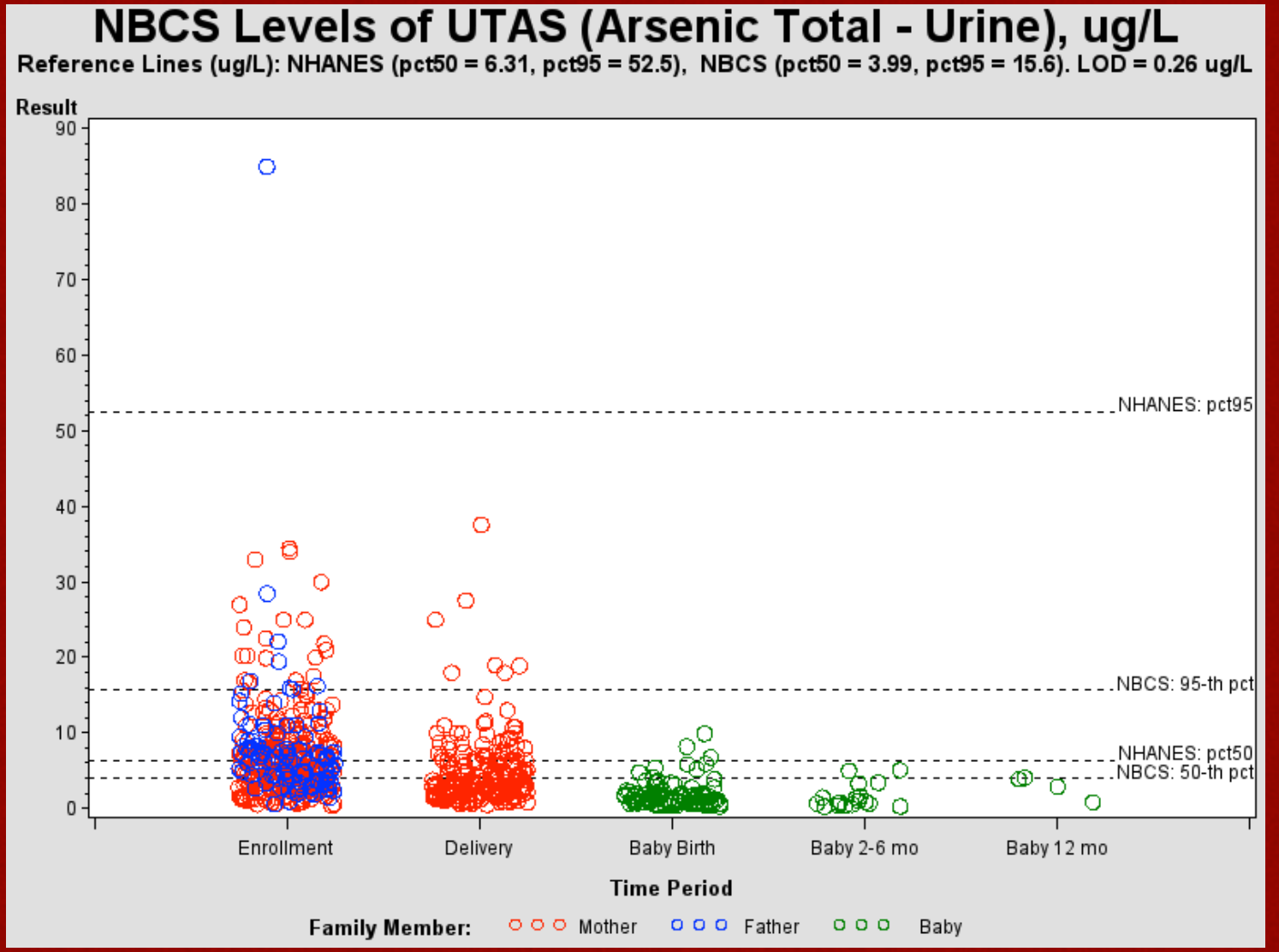
	Blood	Urine	Meconium
Mother	➢ Enrollment ➢ Delivery	➢ Enrollment ➢ Delivery	
Father	➢ Enrollment	➢ Enrollment	
Baby	➢ Birth (cord blood) ➢ 2-6 months of age ➢ 12 months of age	➢ Birth ➢ 2-6 months of age ➢ 12 months of age	➢ Birth



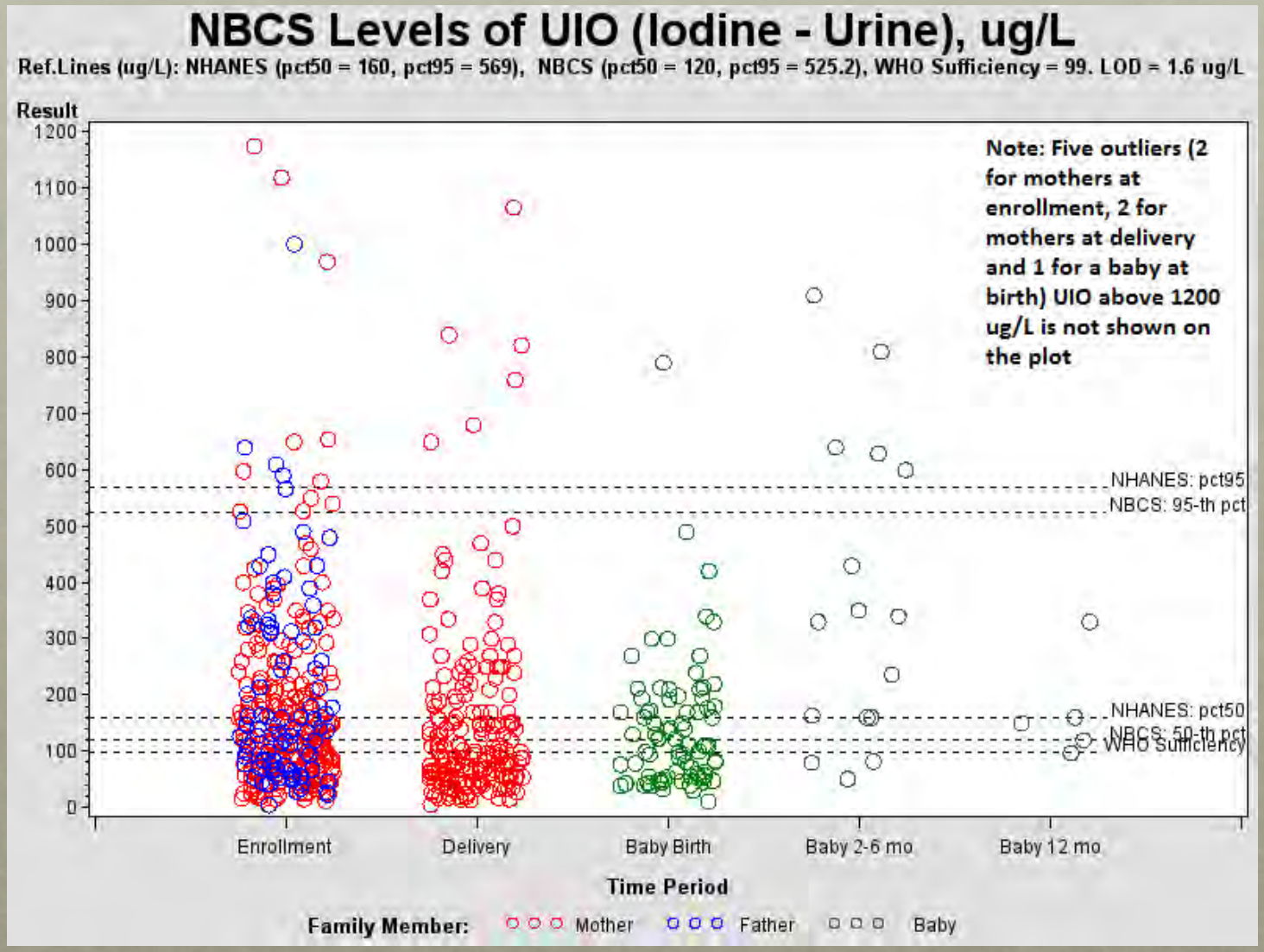
Uranium distributions consistent across all service units

- Now have sufficient data to begin examining relationships between moms, dads, babies; babies over time; and relationships to exposure sources
- Cannot directly address placental transfer, U in urine at birth a concern
- Concern that babies exposures increase & at levels 3x greater than expected for adults (NHANES)

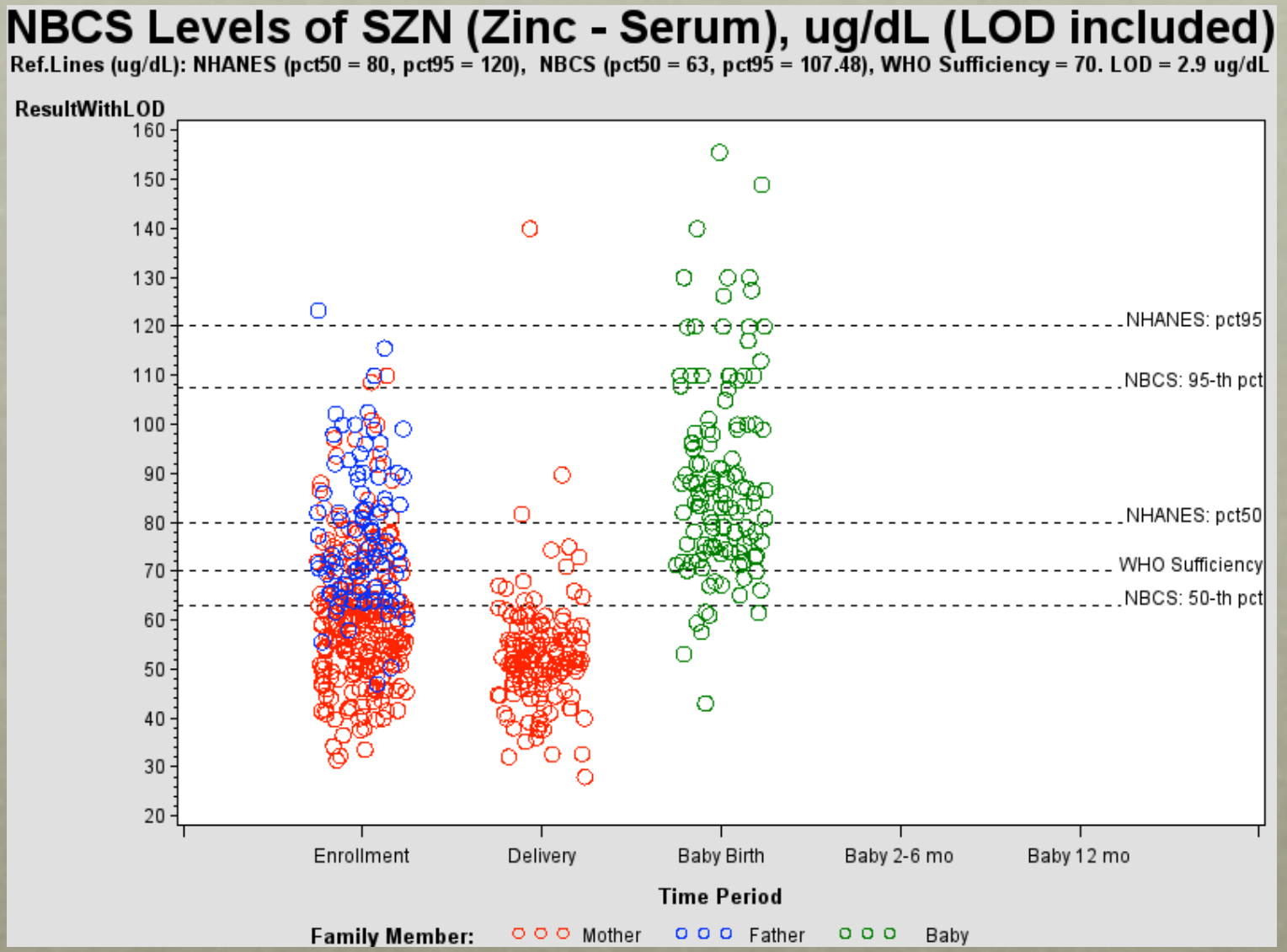
All percentile comparisons are to NHANES 2010-2011 adults – no infant comparisons found.



Levels lower than anticipated based on water and mine waste analyses



- Critical for thyroid function, normal organ & CNS development
- Highly variable analyte
- Best viewed as indicator of population sufficiency
- No prior data on Navajo
- Suggests potential for population deficit
- Preventable – supplementation, increased dairy, fish, oral supplements – Could be clinically addressed ASAP to improve birth outcomes
- But -- None of high-iodine foods in Navajo diet!



- Serum zinc deficiency common in pregnancy
- Sufficiency of majority of babies and dads suggests serum not best marker of functional sufficiency
- VICTER: Hudson, Ho, Lewis – synergy of Zn deficiency, metal exposure, oxidative stress & DNA repair *in vitro, in vivo,* and in human samples

Parallel efforts

Understanding mechanisms of toxicity

Likely Exposure Pathways

Inflammation – Immunity – Metal exposure

(MacKenzie, Erdei, Ong, Rubin, Pollard)

- **Our previous tribal studies showed elevated ANA with As exposure**
  - (Ong et al., *Autoimmune Diseases*, 2014)
  - **Specific auto-antibodies consistent with environmental autoimmunity (e.g. drug-induced Lupus)**
- **Elevated prevalence of ANA in older DiNEH cohort (48% by clinical screen)**
- **NBCS - 20% of 14-45 yo sample ANA positive (M=F) (n=40)**
- **Unexpected in this age range**
  - **NHANES data – 13.9% prevalence** (Satoh et al., *Arthritis and Rheumatism*, 2012)
  - **Hg study from NHANES data – 16%** (Somers et al., *EHP*, 2015)

DNA Damage

(Hudson, Cooper, Dashner, MacKenzie)

- Comet assays on samples from 36 NBCS mothers (mean age 26)
- Number of cells with damage increases with exposure
  - Urine As : Urine U interaction significant predictor of damage (p=.0007)
  - 3-way interaction shows Zn reduces synergistic increase in damage linked to As:U interaction (p = 0.006)
  - Indications that supplements *prior to* pregnancy are important in reducing damage
- VERY PRELIMINARY RESULTS!!! Replicating in additional samples
- Consistent with our laboratory studies
- Suggest protective intervention possible to reduce damage

Understanding transfer at soil:water and soil:air interface

Serafina Nez and her Mother Helen. Members of Tachee Uranium Concerns Committee that requested these analyses

Tachee/Blue Gap – community concerns about living with waste – historical developmental disabilities in children, consumption of contaminated water

(Cerrato, Blake, Shuey)

Abandoned Uranium Mine Waste (Northeastern Arizona):

Elevated **U** (6,614 mg kg^{-1})

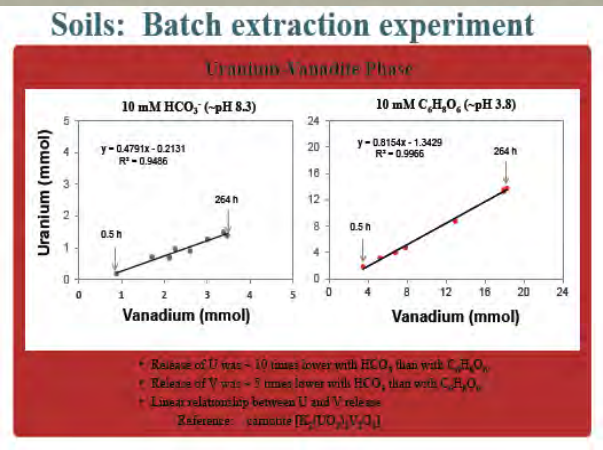
Co-occurring metals (e.g. **As**, **V**, **Fe**)

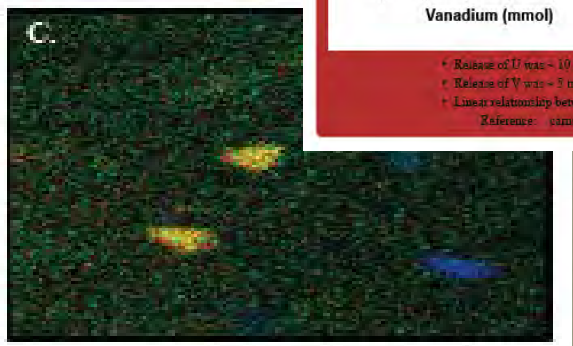
U in Water (Spring):		EPA MCL for U
67 – 170 µg L^{-1}	**>**	30 µg L^{-1}

METALS Monograph #1
Results presented to community, NNEPA, NNDOJ

→ USEPA Region 9

→ site now prioritized for clean-up

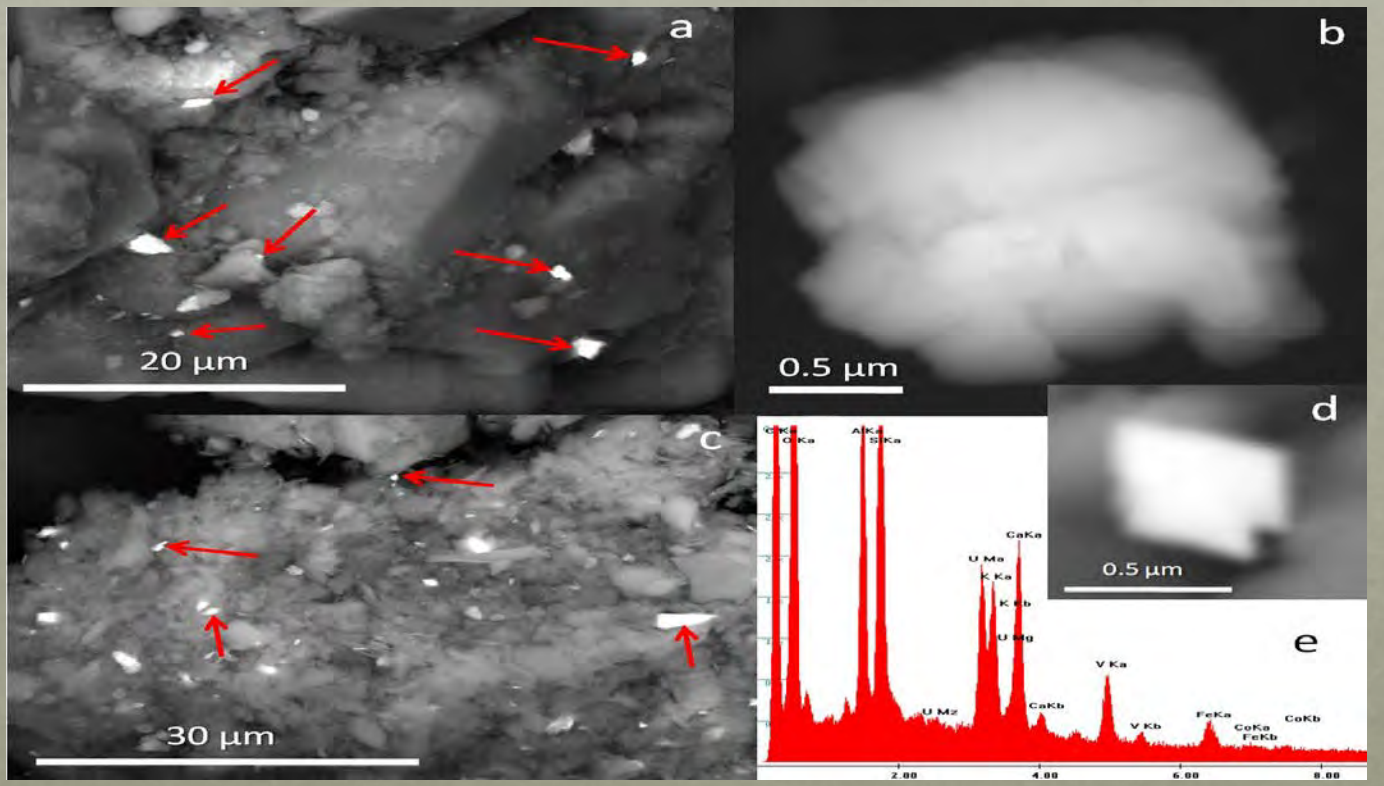




C.) Elemental mapping performed on MW1. Blue=Iron, Red=Uranium, Green=Vanadium, and Yellow reflects combined U and V.

Transport of waste at Air:Soil interface

BACKSCATTERED ELECTRON IMAGES and EDS SPECTRUM of CARNOTITE [$K_2(UO_2)_2V_2O_8$] IN AUM WASTE (Brearly)



Air sampling to begin this spring (Campen, Gonzales, Shuey, Nez)

- a, b, c and d) BSE images showing dispersed micron to submicron, free carnotite particles (arrowed) in mine waste,
- e) EDS spectrum of carnotite particles.

Sites vary, are large, and extremely close to Communities

Affect Navajo and other tribes in west

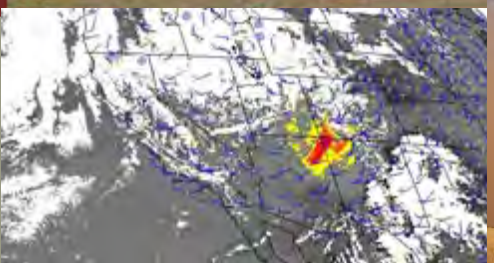


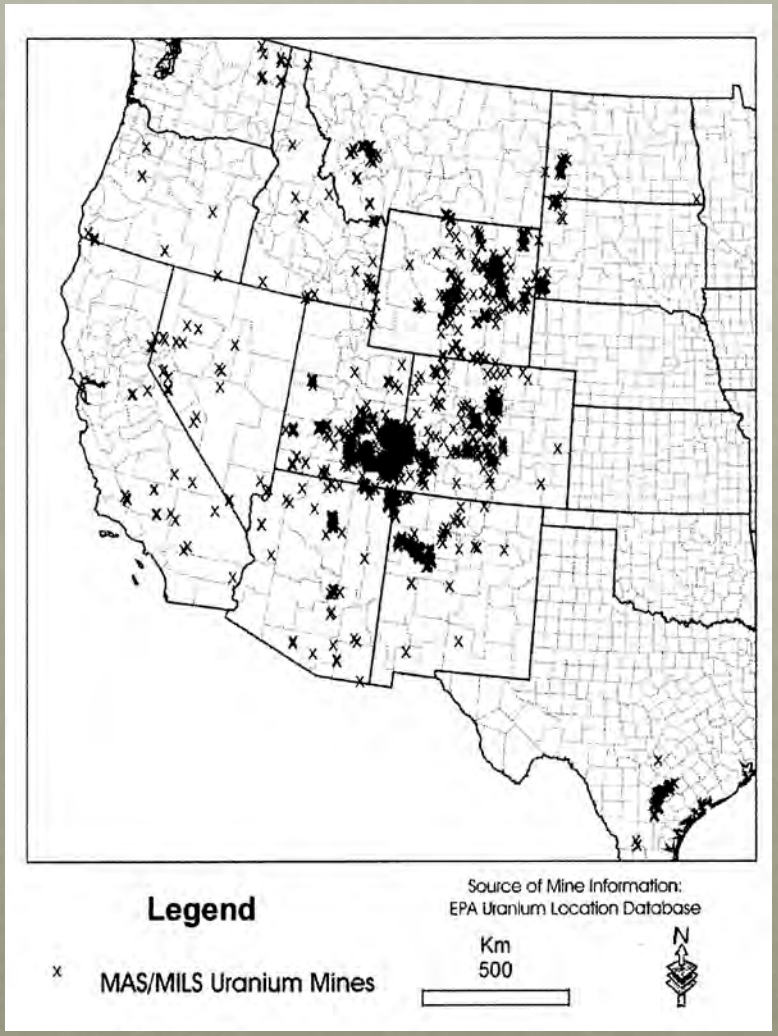
Photo montage shows spring winds resuspending dust from Old Church Rock Mine site (right) onto Navajo grazing lands (left), April 2003.

As Dust Storms increase, What IS In the Dust????

Phoenix Tuesday
March 2014

Tribal Lands and the Uranium Legacy

Uranium one of many minerals mined in Western U.S. primarily for weapons development.



The Uranium Legacy of the Western U.S.

- USEPA estimates:
  ~10,400 abandoned uranium "mine features" in 15 western states
- U.S. Bureau of Mines estimates:
  ~4,100 discrete uranium mines

Source: http://www.epa.gov/rpdweb00/tenorm/uranium.html

GAO testimony in House – 2011

- 161,000 abandoned hardrock mine sites in 12 Western states and Alaska
- 33,000 have degraded environment through contamination of surface and groundwater OR leaving arsenic-contaminated tailings
- 12 Western states and Alaska have the highest percentages of AI/AN population

Source: http://www.gao.gov/assets/130/126667.pdf

Is this OK????????

Thank you

FROM THE NBCS TEAM!
UNM-CEHP, SRIC, NNDOH, NAIHS, CDC/ATSDR