Assessing And Reducing Drinking Water Metal Exposure On The Navajo Nation Using Geospatial Technology

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INTRODUCTION

BACKGROUND

The Navajo Nation (NN) is the site of extensive historical resource extraction. Uranium mining for the Cold War occurred throughout the NN and there remains a legacy of more than 1,100 mine features.

- Navajo communities have expressed concerns about the impact of uranium mining and waste on the land, water and human health

Additionally, the geology of the Colorado Plateau contributes to the occurrence of dissolved metals in groundwater. For example, arsenopyrite is a mineral commonly found in aquifers on the NN. As a result, contaminated **drinking water is one possible metal exposure route** for NN residents.

Drinking Water

There 182 public water supply (PWS) systems on the NN. Access to PWS remains heterogeneous:
- An estimated 54,000 Navajo use water from unregulated drinking water sources (UDWS)

Due to the high rate of UDWS use, numerous agencies (state, federal and community) have conducted sampling to test for water contaminants in unregulated wells.
- However, these data sources have never been fully integrated

OBJECTIVES

- Create a relational database to store water quality data for NN unregulated water wells
- Evaluate the occurrence of inorganic contaminants in unregulated water sources
- Spatially analyze the distribution of groundwater contaminants on NN

METHODS

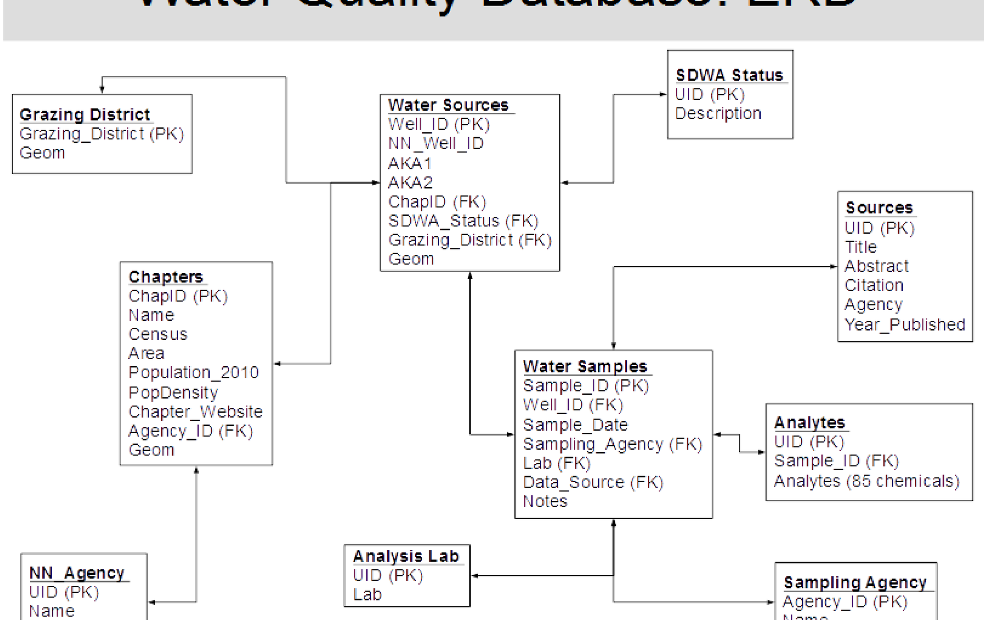
Data Compilation

- Compiled data from multiple sources:
  - US Army Corps Of Engineers
  - US Geological Survey
  - Church Rock Uranium Monitoring Project
  - US Environmental Protection Agency
  - NN Environmental Protection Agency
  - Centers For Disease Control and Prevention
  - DiNEH Project

Relational Database

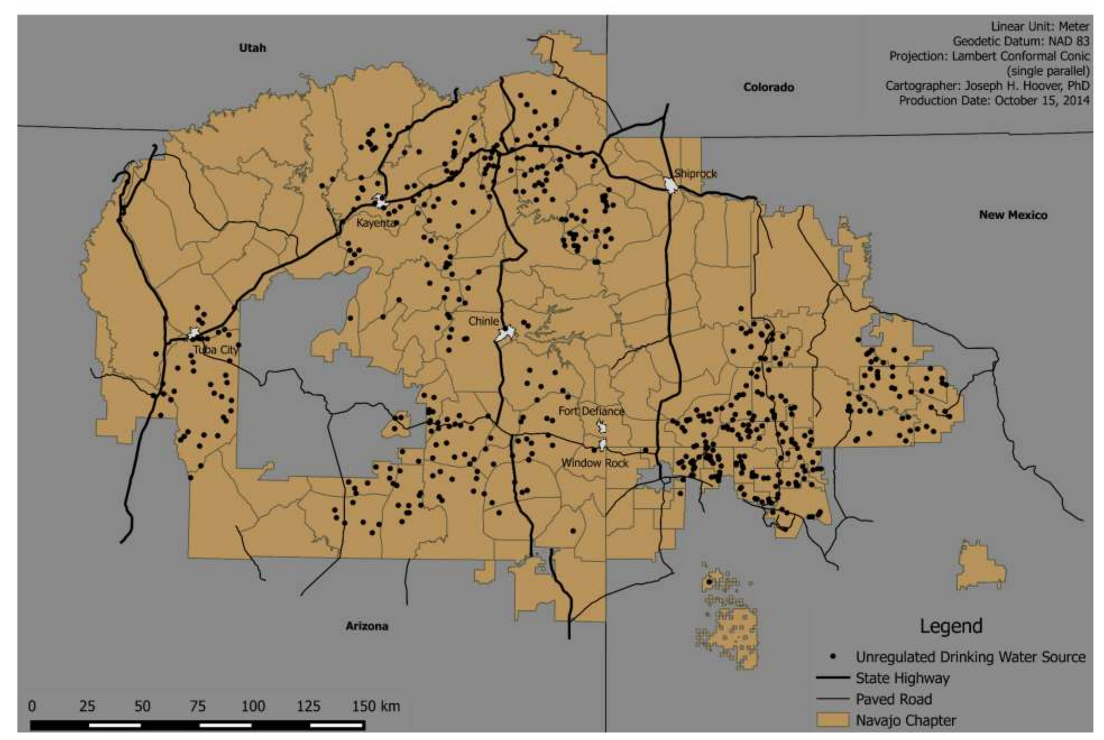
- Created a relational database using PostgreSQL 9.3.5 and PostGIS 2.1.3

Water Quality Database: ERD



RESULTS

Identified Unregulated Drinking Water Sources



Water Quality Mapping

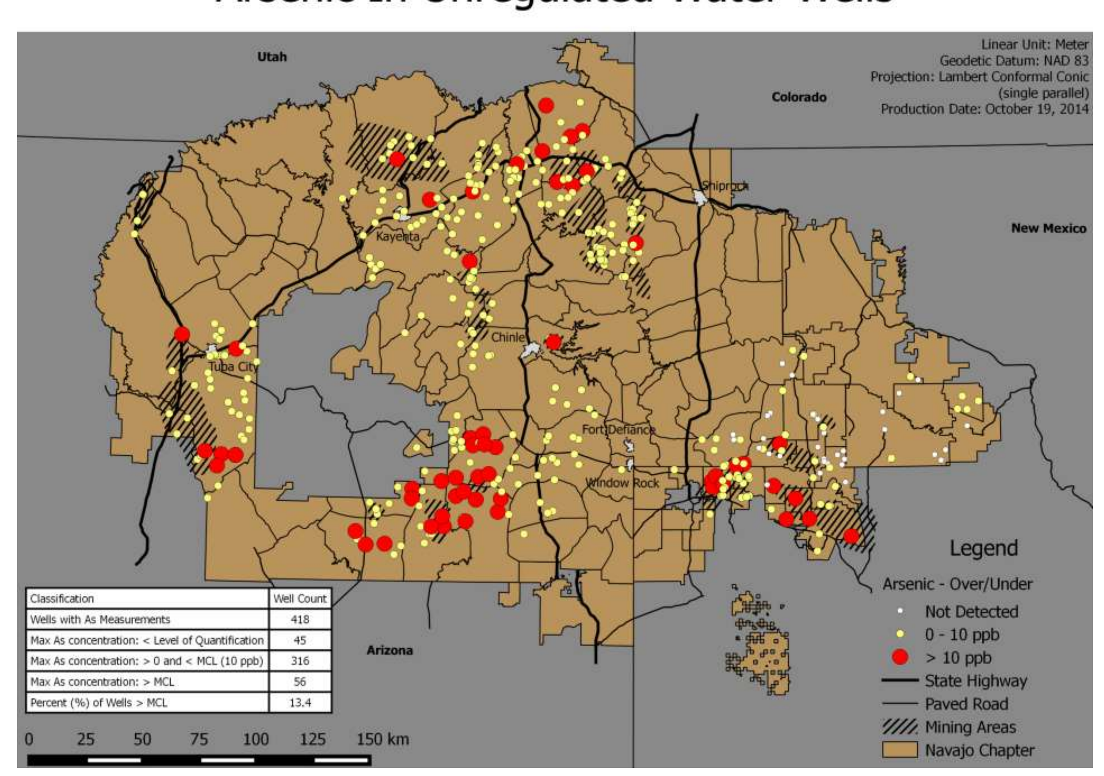
Compiled water quality data for 85 analytes from available sources. Linked the water quality records with geographic locations of unregulated water wells.

- Inorganic metal analyte concentrations for 427 UDWS (~17% of all UDWS on NN)
  - Sampled wells are unevenly distributed throughout NN with location bias near former mining areas
  - Minimal water quality monitoring in Western and Shiprock Agencies
  - Sampled wells are located in 68 chapters
  - Range: 1 sampled UDWS per chapter to 32 sampled UDWS per chapter

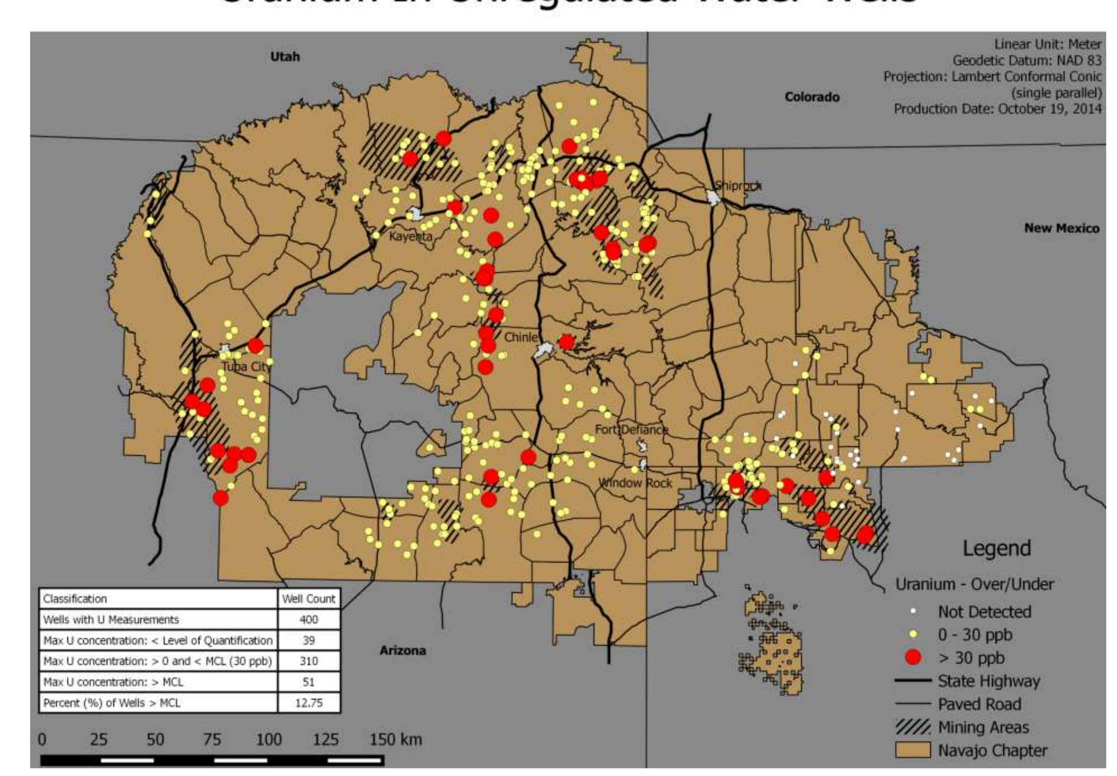
Spatial Autocorrelation

- Local spatial clustering of arsenic contaminated UDWS in southern NN
  - Three clusters: Two clusters are in mining areas and the third cluster could be attributed to the presence of arsenic bearing minerals in the aquifer material.
- Elevated uranium values are spatially co-located with former mining areas
- Moderate spatial autocorrelation of Safe Drinking Water Act Maximum Contaminant Level (MCL) exceedances and local clustering of wells with MCL exceedances

Arsenic In Unregulated Water Wells



Uranium In Unregulated Water Wells



Contaminant	MCL* (ppb)**	Wells With At Least 1 Measurement > MCL	# Of Wells With Measurements	% Of Wells Exceeding MCL
At least 1 MCL Exceedance	-	111	427	26
As	10	56	418	13.4
U	30	51	400	12.8
F	4,000	5	113	4.4
Se	50	17	405	4.2
As+U	-	15	397	3.8
Pb	15	11	413	2.7
Sb	6	4	292	1.4
Hg	2	3	293	1.0
Cu	1,300	1	413	0.2
Cd	5	1	411	0.2
Ba	2,000	1	406	0.2
Be	4	1	404	0.2
Cr	100	0	410	0.0

*Maximum Contaminant Level as specified by the regulations implementing the Safe Drinking Water Act (40 CFR 141). **parts per billion (or micrograms per liter).

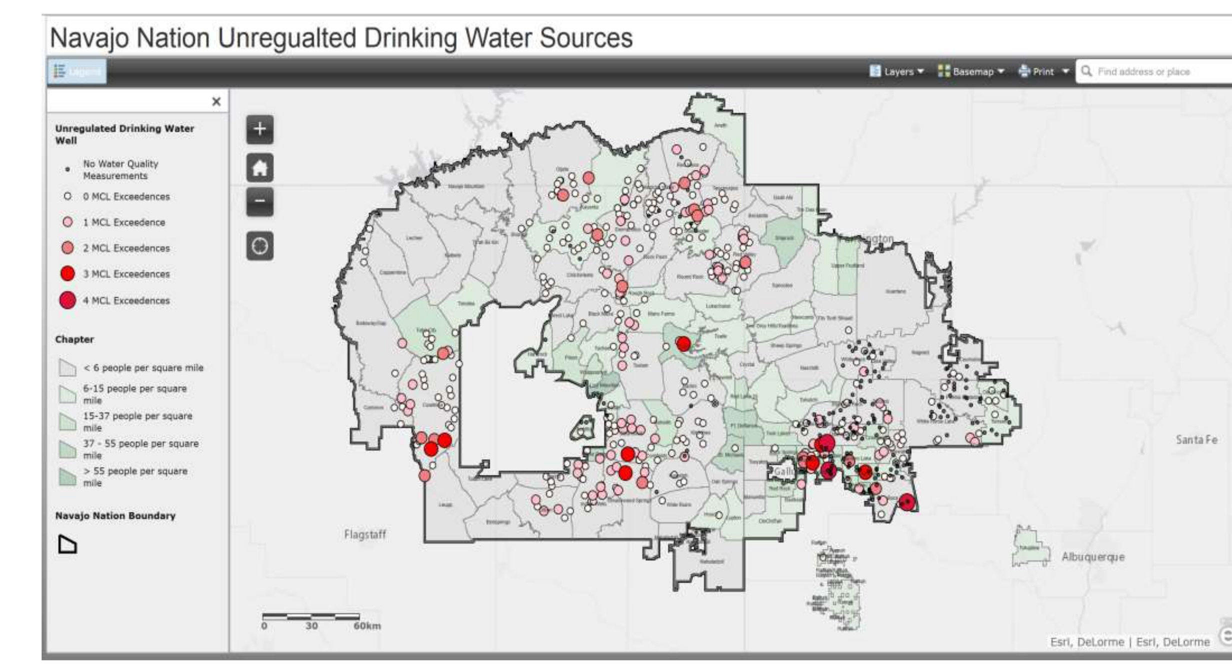
Safe Drinking Water Act Exceedances

ENVIRONMENTAL LITERACY

Environmental (and Health) Literacy

A need exists to communicate these water quality data to NN residents and resource users. Previous research has demonstrated that Internet Geographic Information Systems (GIS) applications are capable of conveying water quality information to users (Hoover et al., 2014).
- Why? Interactive, customizable, dynamic and user friendly

- **Goals**: Develop an integrated environmental literacy education program that includes geospatial technology
- Work to date includes development and testing of a publicly available Internet GIS application that displays water quality information for NN UDWS



DISCUSSION

Limitations

Radionuclide and bacterial analytes have been collected but not included in this analysis. Additional water quality data exist will be added to the database for analysis. Currently, sampled water wells are biased towards mining areas. Limited water quality sampling data for other areas of NN
- PWS water quality measurements are one possible source of additional data to reduce this bias

Need to better evaluate the reliability and quality of available data:
- Many data sources lack metadata such as analyte analysis protocols, collection methods and QA/QC
- The current data remain useful, however, for well screening and identifying locations for additional sampling
- Limited information available regarding human use of UDWS

Future Work

- Incorporate additional water quality data from other sources and include metadata for more comprehensive assessment of data reliability
- More robust spatial analysis and evaluation of spatial bias in sampling
- Future work will incorporate data from biomonitoring and home environmental assessments into online GIS tool

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