2023 NM WRRI Student Water Research Grant Progress Report
Final Report

1. **Student Researcher:** Mary Frances Bibb, M.S. Natural Sciences-Geology
Faculty Advisor: Jennifer Lindline, Ph.D.

2. **Project title:** Acid Rock Drainage and Metal Leaching Potential at the Jones Hill Deposit, Pecos, NM

3. **Description of research problem and research objectives.**
The Upper Pecos River is one of New Mexico's most iconic rivers, sustaining the local agricultural community, providing exceptional recreational opportunities, and offering many rich and diverse ecological values. In the early 1900s, the river corridor was the site of a historic lead- zinc mine – the Tererro Mine – from which AMD led to high metal loads and periodic fish kills. The Tererro Mine has been in the reclamation phase for more than twenty years. A 2019 proposal from a mining company to conduct exploratory drilling for gold, copper, and zinc at the Jones Hill deposit 8 km southwest of Tererro is currently in review by the New Mexico Mining and Minerals Division of the New Mexico Energy, Minerals, and Natural Resources Department. The objectives of the proposed research are to understand the acid-generating potential and the neutralization potential of the mine rocks in order to predict acid rock drainage and inform exploration and remediation activities.

4. **Description of methodology employed.**
This project is utilizing a combination of methods, including:
   - Thin section analysis on a subset of samples from drill core samples to determine the mineral content and textural relationships of rocks from representative geologic units that have a high probability of becoming waste rock during mining due to proximity to high-grade ore.
   - Standard acid-base accounting (ABA) analysis and net acid generation (NAG) assessment to measure the balance between the acid-generating potential (AGP) and acid neutralization potential (ANP). The net neutralizing potential (NNP) is the difference between (ANP-AGP).
   - Rock magnetic experiments, including bulk magnetic susceptibility and low-field susceptibility versus temperature tests, to characterize the sulfide mineralogy of the deposit.
   - Water chemistry analysis to determine the baseline hydrogeochemistry of the Upper Pecos River upstream of the Jones Hill deposit and two creeks running off Jones Hill (Indian Creek and Macho Creek) into the Upper Pecos River.

5. **Description of results; include findings, conclusions, and recommendations for further research.**
The research is an intermediate stage. The field site has been surveyed, literature has been reviewed, partial sampling has been conducted, and analytical services have been conducted. Additional rock core and grab water samples are being collected and processed for the information noted above.

Mineralogy of Jones Hill Deposit. The team has analyzed nearly 500 feet of cores from 5 different samples. The majority of site rocks are igneous plutonic rocks with a range of granitoid compositions (major quartz, plagioclase feldspar, and potassium feldspar). The igneous rocks range from being fresh and intact to highly fractured and hydrothermally altered (talc, serpentine, clays). Minor sedimentary rocks include sandstone, limestone, and shale. The igneous rocks have ubiquitous pyrite. Pyrite ranges from a modal phase (1-5%) to an accessory phase. Pyrite is notable because its oxidation produces extremely acidic drainages (as low as pH 2) and heavy metal leaching. Other identified sulfide minerals include chalcopyrite, pentlandite, and galena.

Geochemical Analysis. Twenty-five rock samples representing the range of rock types, hydrothermal alteration, and ore mineralization were cut from Jones Hill Cores. Samples included 24 metaigneous rocks and one sandstone. Samples were cleaned, labeled, bagged and sent to SVL Analytical, Inc. (Kellogg, ID) for standard acid-base accounting (ABA) analysis and net acid generation (NAG) assessment. All samples weighed between 300-500 g. The SVL, Inc. project manager reviewed the samples for the complete chain of custody. SVL Analytical, Inc. tested for:

- Net Acid Generated pH
- Paste pH
- Acid Base Accounting
- Acid Generating Potential
- Non-extractable Sulfur
- Non-sulfate Sulfur
- Pyritic Sulfur
- Sulfate Sulfur
- Total Sulfur
- Acid Neutralization Potential

Geochemical data are provided in Table 1. Four of the metaigneous rocks bearing sulfide minerals had a pH < 4.5 and classified as Potentially Acid Forming. These same samples were at or near the Potentially Acid Forming threshold (NNP < -20) which is calculated using the difference between Acid Neutralization Potential and Acid Generating Potential. The majority of samples were Non Acid Forming or Acid Consuming. Review and interpretation of the data are still in progress. Additional country rock samples are being collected and analyzed to best understand the acid generating versus acid neutralizing ability of the potential waste rock material at the proposed mine site.

Rock Magnetic Experiments. Analyses are in progress.

Water chemistry analysis. The project enlisted the services of EPA-certified laboratory Eurofins Albuquerque. Eurofins provided sample kits containing 3 samples per site for each sampling effort, as well as labels, a cooler, chain-of-custody forms, plastic bags, and sampling instructions. A sample control manager reviewed the bottle kits prior to shipment and reviewed the submitted samples for complete chain-of-custody, temperature, volume, and other requirements.

Eurofins Albuquerque utilized the following methods:

- EPA Method 200.7 for Metals Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} (ICP) – Total Recoverable
- EPA Method 200.8 for Metals Sb, As, Be, Cd, Se, Tl, Cu, Pb, Zn – Total Recoverable
- EPA Method 300.0 for Anions (Ion Chromatography): Br^{-}, $(NO_3)^{-}$, Cl^{-}, $(NO_2)^{-}$, (PO_4^{3}), and $(SO_4)^{2-}$, and F^{-}.

Grab samples were collected in Spring 2024 (spring runoff) following NM Environment Department standard operating protocols for surface water sample collection. Results showed:

- The Upper Pecos River belongs to the Calcium-type hydrochemical facies. Calcium was the dominant metal (17-40 mg/L), with relatively lower amounts of Magnesium, Potassium, and Sodium (0 - 3.5 mg/L).
- Phosphorous/Orthophosphate was not detectable in the sampled waters.
- Nitrogen/Nitrate $(NO_3)^{-}$ (mg/L) levels ranged between 0 to 0.86.
- Nitrogen/Nitrite $(NO_2)^{-}$ (mg/L) values ranged between 0.0971 - 0.113.
    - Nitrogen values are below the total Nitrogen threshold of 0.25 mg/L.
- Sulfate levels ranged between 6.4 - 12 mg/L.
- Chloride levels ranged from 0.54 - 0.94 mg/L.
- Metals Sb, As, Be, Cd, Se, Tl, and Zn were not detected in the sampled waters.
- Cu was detected in two samples (0.50 ppb and 1.9 ppb) and Pb was detected in one sample (0.059 ppb). Both are below the federal government drinking water action levels (Cu 1300 ppb and Pb 15 ppb) (56 FR 26548 § 141.80 (c) (1) and (2)).

6. **Provide a paragraph on who will benefit from your research results. Include any water agency that could use your results.**
The research results will be shared with the Upper Pecos Watershed Association (UPWA), the New Mexico Environment Department Surface Water Quality Bureau (NMEDSWQB) and Comexico, LLC. These data will assist UPWA in understanding threats to the Upper Pecos River, the NMED SWQB in knowing potential impairments to the river, and Comexico, LLC in developing exploratory drilling activities and related reclamation plans.

7. **Describe how you have spent your grant funds. Also, provide your budget balance and how you will use any remaining funds. If you anticipate any funds remaining after August 30, 2024, please contact Carolina Mijares immediately. (575-646-7991; mijares@nmsu.edu).**
To date, approximately 93% of the grant funds has been invoiced for the intended water chemistry analysis with Eurofins Albuquerque, NM (Formerly Hall Environmental) and rock chemistry analysis with SVL Analytical, Inc. A fraction of the budget remains ($720; 7%) which is requested for Fall baseflow water sampling.

8. **List presentations you have made related to the project.**
Bibb, M.F. and Lindline, J., 2024, Acid Rock Drainage and Metal Leaching Potential at the Jones Hill Deposit, Pecos, NM, Poster presentation at the 68th Annual New Mexico Water Conference (November 8-9, 2023), Abstract 36 in the Poster Abstracts Program.

Bibb, Mary Frances and Lindline, Jennifer, 2024, Acid Rock Drainage and Metal Leaching Potential at the Jones Hill Deposit, Pecos, NM. Poster presentation at NMHU Research and Creative Showcase Day (April 26, 2024).

9. **List publications or reports, if any, that you are preparing. For all publications/reports and posters resulting from this award, please attribute the funding to NM WRRI and the New Mexico State Legislature by including the account number: NMWRRI-SG-2020.**
   The research funded herein is part of the student's Master's thesis. Mary Frances will continue collecting, reducing, and interpreting the data over the next academic year. Her timetable includes defending her thesis in April 2025 and graduating in May 2025. Post-graduation, Mary Frances will publish her findings and acknowledge NMWRRI funding.

10. **List any other students or faculty members who have assisted you with your project.**
    - Jennifer Lindline, Ph.D. (NMHU Faculty Sponsor)
    - Marine Foucher (NMHU Post-Doctoral Researcher)

11. **Provide special recognition awards or notable achievements as a result of the research including any publicity such as newspaper articles, or similar.**
    The student researcher was highlighted in the Upper Pecos Watershed Association August 2023 newsletter, as well as New Mexico Water Resources Research Institute's February 2024 eNewsletter (New Mexico Water eNews February 2024 (mailchi.mp)).

12. **Provide information on degree completion and future career plans. Funding for student grants comes from the New Mexico Legislature and legislators are interested in whether recipients of these grants go on to complete academic degrees and work in a water-related field in New Mexico or elsewhere.**

    After completing her graduate degree (May 2025), Mary Frances wants to work in environmental law and policy. She intends to remain in Northeastern New Mexico and serve its rural communities with water resources science and management issues.

Project Photographs

Marine Foucher (left) and Mary Frances Bibb (right) pulling core boxes for study from the core library at the New Mexico Bureau of Geology and Mineral Resources (04/18/24). Photo c/o Jennifer Lindline.

Team studying core samples (04/18/24) Photo c/o Marine Foucher.

Mary Frances Bibb presenting her project at the annual New Mexico Highlands University Research and Scholarly Activity Day (04/26/24). Photo c/o Marine Foucher.

Jennifer Lindline (left) and Mary Frances Bibb (right) at the New Mexico Bureau of Geology and Mineral Resources core library (04/18/24). Photo c/o Marine Foucher.

Boxes containing Jones Hill Sample 243 (50 feet) (06/13/24). Photo c/o Jennifer Lindline.

Boxes containing Jones Hill Sample 245 (10 feet) (04/18/24). Photo c/o Jennifer Lindline.

Photo of discreet cubes of pyrite and concentrated vein of Cu-sulfide minerals in rock from Jones Hill Sample 250 (0613/24). Photo c/o Jennifer Lindline.

Concentrated vein of Fe-Cu sulfide minerals in rock from Jones Hill Sample 247 (04/18/24). Photo c/o Jennifer Lindline.

Dr. Lindline using rock saw to cut and prepare rock samples for testing (07/30/24). Photo c/o Mary Frances Bibb.

Cut, dried, and catalogued samples prior to shipment to SVL, Inc. for chemical analysis (07/30/24). Photo c/o Mary Frances Bibb.

Table 1. Acid Base Accounting and Net Acid Generation pH @ 22°C Results.

Core ID	Rock Sample	ABA	AGP	Non-Extract Sulfur	Non-Sulfate Sulfur	Pyritic Sulfur	Sulfate Sulfur	Total Sulfur	ANP	NAG pH@20.7°C	Paste pH@18.0°C
		Tonne$CaCO_3$/k Tonne	Tonne$CaCO_3$/k Tonne	%	%	%	%	%	Tonne$CaCO_3$/k Tonne	pH units	pH units
	Method	Modified Sobek	Modified Sobek	Modified Sobek	Modified Sobek	Modified Sobek	Modified Sobek	Modified Sobek	NV Modified Sobek	AMIRA P387A	EPA 600/2-78-054 mod
235	24JHD_235-1.2075	-241	249	<0.04	7.97	7.97	1.12	9.09	7.6	2.74	9.0
236	24JHD_Pecos47.63	3.8	<1.2	<0.04	<0.04	<0.04	0.04	0.04	3.8	5.84	7.0
236	24JHD_J47.4996	14.5	1.4	<0.04	0.06	0.04	<0.04	0.04	15.9	7.21	8.9
243	24JHD_243-1.06	2.9	<1.2	<0.04	0.04	<0.04	<0.04	<0.04	2.9	6.38	9.0
243	24JHD_243-1.975	4.3	3	<0.04	0.10	0.10	<0.04	0.10	7.2	7.03	9.3
243	24JHD_243-2.17	4.9	3.6	<0.04	0.12	0.12	<0.04	0.12	8.6	7.30	9.1
243	24JHD_243-3.3175	<1.2	2.4	<0.04	0.08	0.08	<0.04	0.10	2.2	6.49	9.0
243	24JHD_243-5.49	3.7	1.9	<0.04	0.06	0.06	<0.04	0.06	5.6	6.62	8.7
245	24JHD_245-1.01	-5.5	5.5	<0.04	0.18	0.18	<0.04	0.18	<0.3	4.01	6.7
245	24JHD_245-3.35	<1.2	<1.2	<0.04	<0.04	<0.04	<0.04	<0.04	1.1	6.33	8.9
245	24JHD_245-4.45	<9.1	9.1	<0.04	0.29	0.29	0.07	0.36	<0.3	3.01	8.1
245	24JHD_245-7.74	<13.2	15.4	<0.04	0.49	0.49	0.06	0.55	2.2	3.42	8.8
245	24JHD_245-9.100	<1.2	<1.2	<0.04	<0.04	<0.04	<0.04	<0.04	<0.3	6.44	9.3
246	24JHD_246-1.0	-4.4	6.2	<0.04	0.20	0.20	0.10	0.30	1.8	5.31	9.3
246	24JHD_246-2.19	<1.2	<1.2	<0.04	0.05	<0.04	<0.04	<0.04	<0.3	5.89	8.9
246	24JHD_246-8.785	-23.9	23.9	<0.04	0.76	0.76	0.14	0.90	<0.3	3.48	8.3
246	24JHD_246-10.106	7.7	28.2	<0.04	0.90	0.90	0.05	0.95	35.8	8.06	8.8
247	24JHD_247-1.02	3.1	2.1	<0.04	0.07	0.07	<0.04	0.09	5.2	5.57	9.3
247	24JHD_247-4.34	<1.2	6.6	<0.04	0.21	0.21	<0.04	0.23	7.4	6.33	9.0
247	24JHD_247-6.51	<1.2	2.6	<0.04	0.08	0.08	<0.04	0.11	3.1	4.67	8.5
247	24JHD_247-7.61	3.0	2.9	<0.04	0.11	0.09	<0.04	0.09	6.0	6.29	8.6
247	24JHD_247-8.72	3.1	<1.2	<0.04	<0.04	<0.04	0.05	0.05	3.1	6.04	8.9
250	24JHD_250-2.12	1.9	1.9	<0.04	0.06	0.06	0.07	0.13	3.8	6.26	9.4
250	24JHD_250-5.475	2.7	<1.2	<0.04	<0.04	<0.04	<0.04	0.04	2.7	5.98	9.0
250	24JHD_250-6.59	17.4	<1.2	<0.04	<0.04	<0.04	<0.04	<0.04	17.4	6.94	8.9