A Pre-PROPOSAL SUBMITTED TO:
Navajo Nation EPA

Investigations of sources of contaminants of concern in the San Juan River as defined by Gold King Mine acid mine drainage release

San Juan River at Shiprock, NM

U.S. Geological Survey
New Mexico Water Science Center
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Summary

Problem. Metals attached to suspended sediments or dissolved in river water are a potential source of contamination to communities that depend on that water for agricultural and public supply. Metals are present in both the water and suspended sediments of the San Juan River as it passes through the Navajo Nation. There is a need to understand the source of metals to the San Juan River within the Navajo Nation to understand whether the sources of metals are from mining legacy or natural deposits and mobility in tributaries and arroyos of the San Juan River.

Objectives. The objective of this work is to identify the sources of metals to the San Juan River in the reach flowing through the Navajo Nation, and to quantify the contribution from each source.

Approach. In order to identify the source of metals in the San Juan River, multiple tasks will be necessary. Here, we propose to: analyze the chemical characteristics of the geologic formations that comprise the San Juan Basin, analyze the chemical characteristics of the bed sediment in tributaries and arroyos that enter the San Juan River, analyze the total and dissolved concentrations of metals in water from the tributaries and arroyos, quantify suspended sediment concentrations in water from these locations, and quantify discharge from selected tributaries and arroyos.

Relevance and Benefits. The Gold King Mine (GKM) release has raised many questions about legacy mining issues and the effects of legacy mining sites on water quality in the southwest. This study will take a closer look at the physical and chemical processes of sediments and metals in the Animas and San Juan Rivers. Results will provide valuable information to the Navajo Nation, which uses the San Juan River as a water source, public drinking-water managers, irrigation districts, other stakeholders, and scientists. This study directly relates to several USGS mission areas including Climate and Land Use Change, Ecosystems, Environmental Health, and Water.

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Introduction

On August 5, 2015, about three million gallons of water and sediment were released from the Gold King Mine (GKM) near Silverton, Colorado, into Cement Creek, a tributary of the Animas River (U.S. Geological Survey, 2016). The release occurred during excavation being conducted as part of an investigation by the U.S. Environmental Protection Agency (EPA) into on-going water releases from the mine and the feasibility of water treatment and further mine remediation (U.S. Environmental Protection Agency, 2016). The GKM, which operated between about 1887 and 1922, is one of numerous abandoned and inactive mine sites that contribute metals and acidity to the Animas River and many of its tributaries (U.S. Environmental Protection Agency, 2015).

Low pH values (less than 3) and elevated concentrations of iron, aluminum, cadmium, copper, lead, zinc, arsenic, and (or) nickel are associated with water most affected by

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historical mining in the area as a result of water flowing through mine workings, across mine-waste dumps, and over and through mill tailings (U.S. Geological Survey, 2007a). Historical mining also has affected the distribution and concentration of metals in streambed sediments (U.S. Geological Survey, 2007a). However, weathering of hydrothermally altered rock not associated with historical mine sites is a substantial natural source of metals and acidity to area streams as well (U.S. Geological Survey, 2007a; U.S. Environmental Protection Agency, 2015). The potential short- and long-term water-quality effects of relatively sudden and large releases of mining-related water and sediment, such as the release that recently occurred at the GKM, are not known to have been previously studied in this watershed.

Downstream of Cement Creek, the Animas River flows primarily southward through Durango in southwestern Colorado and into northwestern New Mexico, where the Animas River joins the San Juan River near Farmington (fig. 1). The San Juan River then flows northwest through the Navajo Nation and into Utah, where it discharges into Lake Powell. Waters of the Animas and San Juan Rivers are also used for crop irrigation. Diversions for public supply and crop irrigation were halted for about 10 days after the GKM release. When restrictions on the use of river water were lifted, New Mexico Environment Department Secretary Ryan Flynn indicated that river water quality had returned to pre-release levels, but that long-term impact studies were needed to determine the full effects of the release (Lohmann, 2015). EPA Regional Director Shaun McGrath similarly indicated that ongoing monitoring would be required to determine long-term impacts on water quality, particularly related to metals in sediments that settled onto the streambed and could be remobilized during storm surges or flooding events (Moreno and Billeaud, 2015).

Now, two years after the release, there is a need to understand the source of metals to the San Juan River; whether the sources are from mining legacy (including the Gold King Mine release), or mobilized from natural deposits in tributaries and arroyos of the San Juan River.

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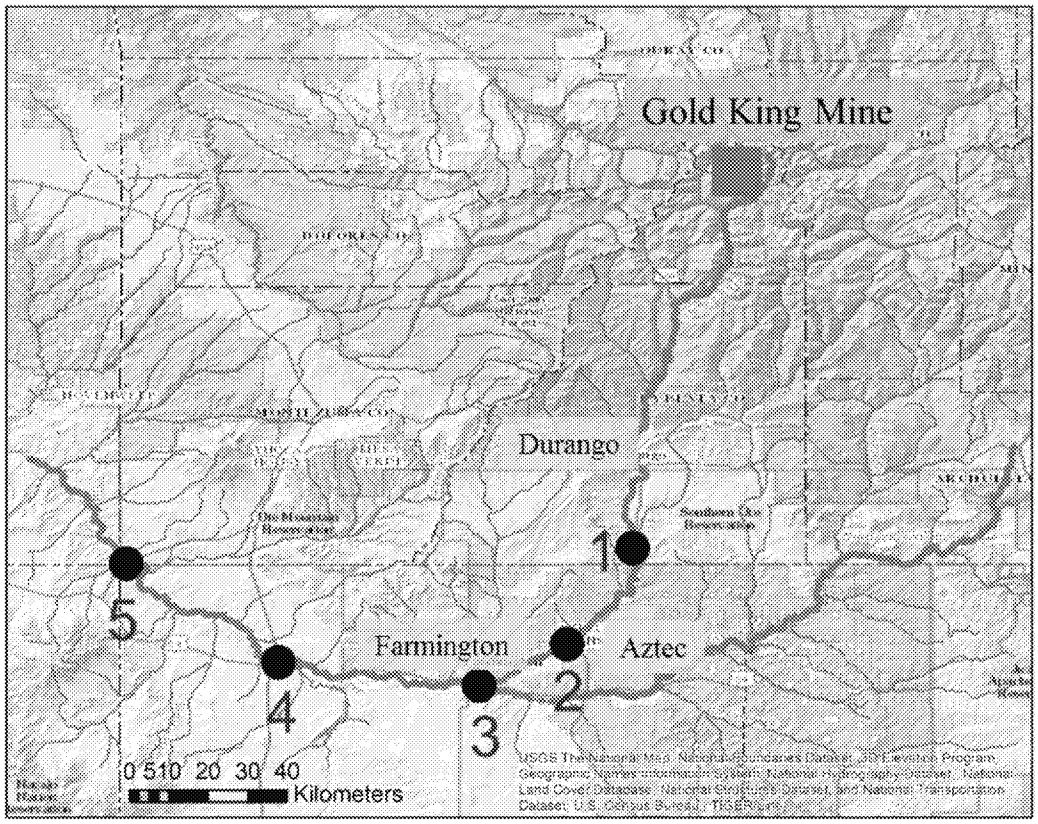

Figure 1. Locations of USGS streamflow gaging stations on the Animas and San Juan Rivers downstream of the Gold King Mine release. Locations of continuous monitoring sondes are shown with black circles and numbers.

Problem

Metals attached to suspended sediments or dissolved in river water are a potential source of contamination to communities that depend on that water for agricultural and public supply. Metals are present in both the water and suspended sediments of the San Juan River as it passes through the Navajo Nation. There is a need to understand the source of metals to the San Juan River within the Navajo Nation to understand whether the sources of metals are from mining legacy or natural deposits and mobility in tributaries and arroyos of the San Juan River.

Objectives and Scope

The objective of this work is to identify the sources of metals to the San Juan River in the reach flowing through the Navajo Nation, and to quantify the contribution from each source.

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Approach

In order to identify the source of metals in the San Juan River, multiple tasks will be necessary. Here, we propose to: analyze the chemical characteristics of the geologic formations that comprise the San Juan Basin, analyze the chemical characteristics of the bed sediment in tributaries and arroyos that enter the San Juan River, analyze the total and dissolved concentrations of metals in water from the tributaries and arroyos, quantify suspended sediment concentrations in water from these locations, and quantify discharge from selected tributaries and arroyos.

Task 1: Compile geochemistry of local geology

The geochemistry of the local geology will provide end member compositions of geochemical signatures in the San Juan River watershed. We will collect published geochemical data on the geology of the San Juan River watershed in addition to sampling and analyzing at least two samples from each formation.

Task 2: Collect and analyze bed sediment in tributaries and arroyos

Two cores to an approximate depth of 6 inches at the mouth of selected tributaries and arroyos along the San Juan River will be collected. A subsample of the core at the surface, middle, and bottom will be analyzed for major and minor analytes such as iron, manganese, lead, arsenic, and others.

Task 3: Install ISCO automated point samplers

Due to the inherent heterogeneity of discharge in the southwest, ISCO automated point samplers will be installed at the mouth of selected tributaries and arroyos to collect water samples. These samplers can be set up to collect water samples at flows higher than a designated depth.

Task 4: Collect point samples to analyze for water quality and sediment by using the ISCO sampler, and stream cross-section integrated samples by using the Equal Width Increment (EWI) method.

Water samples to be analyzed for total and dissolved water quality and suspended sediment concentration will be collected at ephemeral sites by using ISCO samplers. Water samples to be analyzed for total and dissolved water quality and suspended sediment concentration will be collected at gaged sites and perennial sites by using the EWI method.

Task 5: Quantify discharge

Due to the ephemeral nature and remote locations of the tributaries and arroyos, it would be cost prohibitive to install traditional USGS streamgaging stations at these sites. However, using a combination of pressure transducers and model-derived stage-discharge ratings, we will estimate discharge at the mouth of the tributary or arroyo channels.

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Task 6: Analyze data.

Data analysis will include comparisons of water quality, fluvial sediment data, geochemical data from geologic formations in the watersheds, and discharge data. The combination of these datasets will be used to create a conceptual model of metal inputs to the San Juan River.

Task 7: Interpretations and Reporting

Results of this study will be disseminated in a USGS Scientific Investigations Report and (or) a journal article. Data will be publically available on NWISWeb.

Relevance and Benefits

The Gold King Mine (GKM) release has raised many questions about legacy mining issues and the effects of legacy mining sites on water quality in the southwest. This study will take a closer look at the physical and chemical processes of sediments and metals in the Animas and San Juan Rivers. Results will provide valuable information to the Navajo Nation, which uses the San Juan River as a water source, public drinking-water managers, irrigation districts, other stakeholders, and scientists. This study directly relates to several USGS mission areas including Climate and Land Use Change, Ecosystems, Environmental Health, and Water.

Quality Assurance Plan

Quality assurance (QA) measures will be followed to ensure completeness and accuracy of the information communicated during the study. The QA objectives for collection and communication of information will:

- Withstand scientific scrutiny
- Be obtained by methods appropriate for the information and its intended use, and
- Be representative and of known completeness and comparability.

All data will be collected in adherence to USGS standards and methods. The water-quality sondes will be operated and maintained as described in Wagner and others (2006). Provisional data from the sondes will be transmitted and made available through NWISWeb applications in real time. The data will be checked multiple times per week for clearly erroneous values that would result in appropriate data censoring and (or) maintenance visits to the affected site(s). The data will be scheduled for working (application of data corrections), checking, and review/approval within 150 days of collection. Cross-section surveys of water-quality parameters will be conducted annually at each site to characterize cross-section variation and vertical stratification. Collection and processing of integrated water samples and of samples obtained by the automatic sampler will follow standard procedures described in the USGS National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated). Provisional water-quality results will be loaded into NWIS and made

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available through NWISWeb applications as reported by the laboratories. Once all data have been reported for individual samples, they will be reviewed and approved as appropriate.

All digital data and models will be reviewed by USGS personnel to ensure proper documentation. The project and project budget will be reviewed by USGS management on a quarterly basis to ensure project timelines are met. USGS products are impartial, credible, relevant, provide timely information, and are equally accessible and available to all interested parties. Laboratory Evaluation Plans (LEPs) must be developed for analytical laboratories utilized in the project in accordance with Office of Water Quality Technical Memorandum 2014.01 ([HYPERLINK "http://water.usgs.gov/admin/memo/QW/qw2014.01.pdf"]).

Water quality quality-control will include QC samples such as field blanks, equipment blanks, and split replicates to be collected during the project. Equipment blanks will be collected a minimum of once from each ISCO. Replicate samples will be collected at each site, with care to capture different hydrologic conditions. Field blanks will be collected at three sites.

Deliverables

Deliverables include release of data on NWISWeb, a USGS Scientific Investigations Report and (or) a journal article.

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Timeline and Budget

This project will occur in FY18 and FY19 with deliverables provided in FY20. The budget has been itemized to show cost per item.

Table 1. Timeline: Begins after finalization of Joint Funding Agreement.

Task	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: Compile geochemistry of local geology												
Task 2: Collect and analyze bed sediment in tributaries and arroyos												
Task 3: Install ISCO automated point samplers												
Task 4: Collect ISCO and EWI water quality and suspended sediment samples.												
Task 5: Quantify discharge												
Task 6: Analyze data.												
Task 7: Develop conceptual model and write report.												

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Table 2. Budget summary.

Location Name	ISCO purchase and installation cost	ISCO sample cost	EWI cost for 1 sample	Number of samples	Total cost for water quality sampling	Measure discharge (year 1)	Measure discharge (year 2)	Water chemistry Analysis (1 sample $1,500)	Total water chemistry analysis	Sediment Concentration (1 sample)	Total sediment concentration cost	Sediment particle-size distribution (1 sample)	Total sediment particle-size distribution cost	Sediment cores (2 per site * 3 samples)	Geology (2 per site)	Data Analysis (one time cost)	Conceptual Model and report writing (one time cost)	Total Cost Sampling and analysis with ISCOS (with overhead	Total Cost Sampling and analysis without ISCOS (with overhead)	Grand Total with ISCOS (including overhead)	Grand Total without ISCOS (including overhead)
Engaged Sites																$48,000	$100,000				
Ojo Amarillo	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Stevens Arroyo	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Westwater Arroyo	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Chaco River	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Eagle Nest Arroyo	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Many Devils Wash	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Rattlesnake Wash	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Salt Creek Wash	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Malpais Arroyo	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Shiprock Wash	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Red Wash	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Cowboy Wash	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
McElmo Creek	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Montezuma Creek	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Recapture Creek	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Cottonwood Wash	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Tsitah Wash	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Desert Creek	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
West Fork Allen Canyon	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Chinle Creek	$ 20,000	$ 200	NA	4	$ 800	$ 10,500	$ 4,500	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 80,684	$ 40,686		
Gaged Sites																					
Animas River	NA	NA	$ 2,000	4	$ 8,000	NA	NA	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 25,087	$ 25,087		
San Juan River at Farmington	NA	NA	$ 2,000	4	$ 8,000	NA	NA	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 25,087	$ 25,087		
La Plata River	NA	NA	$ 2,000	4	$ 8,000	NA	NA	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 25,087	$ 25,087		
San Juan River at Fruitland	NA	NA	$ 2,000	4	$ 8,000	NA	NA	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 25,087	$ 25,087		
San Juan River at Shiprock	NA	NA	$ 2,000	4	$ 8,000	NA	NA	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 25,087	$ 25,087		
San Juan River at Four Corners	NA	NA	$ 2,000	4	$ 8,000	NA	NA	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 25,087	$ 25,087		
San Juan River near Bluff, UT	NA	NA	$ 2,000	4	$ 8,000	NA	NA	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 25,087	$ 25,087		
Mancos River	NA	NA	$ 2,000	4	$ 8,000	NA	NA	$ 1,500	$ 6,000	$ 150	$ 600	$ 200	$ 800	$ 300	$ 100			$ 25,087	$ 25,087		
																	Sub Total				

Budget Summary Explanation

The budget provided in this pre-proposal estimates the cost of evaluating the geochemical signatures in tributaries and arroyos that enter the San Juan River. The USGS gaging stations located from Farmington, NM to Bluff/Mexican Hat, UT are listed and will be used in the evaluation as sampling locations and discharge data. In addition, the major arroyos and tributaries between Farmington, NM and Mexican Hat, UT are listed. The final number of sampling sites will be decided upon once funding availablility is determined. The USGS will work with the Navajo Nation EPA to select the sites to sample and how many times to sample at each site. For this budget, we have chosen four samples at each site, which will help to increase the quality of the data. The columns listed in Table 2 are defined as follows:

Location Name: The name of the river site, tributary or arroyo.
ISCO purchase and installation cost: The cost to purchase a new ISCO automated sampler and securely install it at a site.
ISCO sample cost: The cost to collect samples from the ISCO.
EWI cost for 1 sample: The cost to collect a water sample of a cross section of the river.
Number of samples: The number of samples estimated to be collected at each site.
Total cost for water quality sampling: The number of samples multiplied by the ISCO or EWI sample cost.
Measure discharge (year 1): The cost to measure and/or calculate discharge from ephemeral channels in the first year. This includes equipment purchases.
Measure discharge (year 2): The cost to measure and/or calculate discharge from ephemeral channels in the second year.
Water chemistry Analysis (1 sample $1,500): The cost to analyze a water sample for chosen chemical constituents.
Total water chemistry analysis: The water chemistry analysis cost multiplied by the number of samples.
Sediment Concentration (1 sample): The cost of analyzing the concentration of sediment in a water sample.
Total sediment concentration cost: The cost of analyzing the concentration of sediment in a water sample multiplied by the number of samples.
Sediment particle-size distribution (1 sample) The cost of analyzing particle size of sediment in a water sample.
Total sediment particle-size distribution cost The cost of analyzing particle size of sediment in a water sample multiplied by the number of samples.
Sediment cores (2 per site * 3 samples): The cost to sample and analyze sediment for channel beds for chemical constituents. Estimate taking 2 sediment cores per site and subsampling 3 depths of the core.
Geology (2 per site): The cost to sample and analyze local geology for chemical constituents. Estimate taking 2 samples per site. Note, the samples may be from a larger spatial extent than the locations of the water samples.
Data Analysis (one time cost): The cost to analyze the data (includes overhead).
Conceptual Model and report writing (one time cost): The cost to develop a conceptual model of the area and write an interpretive report (includes overhead).
Total Cost Sampling and analysis with ISCOS (with overhead): The total cost of sampling, equipment, installation, and sample analysis that includes the ISCOs. Overhead is included.
Prices are shown including ISCOS and without. The ISCOS increase the price of the project and may not be ideal, however that decision will have to be made based upon funding availability.
Total Cost Sampling and analysis without ISCOS (with overhead) The total cost of sampling, equipment, installation, and sample analysis that does not include the ISCOS. Overhead is included.
Grand Total with ISCOS (including overhead): The final cost with ISCOS and overhead included.
Grand Total without ISCOS (including overhead): The final cost without ISCOS but with overhead included.

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References

Abollino, O., Aceto, M., Malandrino, M., Sarzanini, C., and Mentasti, E., 2003, Adsorption of heavy metals on Na-montmorillonite. Effect of pH and organic substances, Water Research, 37, 1619-1627.27, 1005-1012, doi:10.1016/j.apgeochem.2012.01.021

Gray, J.R., and Gartner, J.W. (2010). "Surrogate technologies for monitoring suspended-sediment transport in rivers," Sedimentology of Aqueous Systems, London, Wiley-Blackwell, Chapter 1.

Hua, X., Dong, D., Liu, L., Gao, M., and Liang, D., 2012, Comparison of trace metal adsorption onto different solid materials and their chemical components in a natural aquatic environment, Applied Geochemistry,

Landers, M.N., Straub, T.D., Wood, M.S., and Domanski, M.M., 2016, Sediment acoustic index method for computing continuous suspended-sediment concentrations: U.S. Geological Survey Techniques and Methods, book 3, chap. C5, 63p., [HYPERLINK "http://dx.doi.org/10.3133/tm3C5" \t "_blank"].

Landers, M. N., and Sturm, T.W., 2013, Hysteresis in suspended sediment to turbidity relations due to changing particle size distributions, Water Resources Research, 49, 5487–5500, doi:10.1002/wrcr.20394.

Lohmann, Patrick, 2015, Restrictions on river water lifted: Albuquerque Journal, Aug. 16, 2015, p. B1.

Moreno, I., and Billeaud, J., 2015, Colo. Mine spill into Animas River reaches NM: Albuquerque Journal, Aug. 9, 2015, p. B1.

New Mexico Environment Department, 2015, Long-term monitoring plan: Evaluating the effects of the gold King Mine wastewater spill in northern New Mexico, https://www.env.nm.gov/riverwatersafety/documents/151020-GKMLongTermMonitoringPlanOfficialDraft-Final.pdf

New Mexico Environment Department, 2017, Gold King Mine Water Spill Long Term Monitoring Plan, https://www.env.nm.gov/wp-content/uploads/2016/01/GKM-Long-Term-Monitoring-Plan-for-2017-Official-Public-Draft.pdf

Topping , D. J. , Wright , S. A. , Melis , T. S. & Rubin , D. M., 2007, High - resolution measurement of suspended - sediment concentrations and grain size in the Colorado River in Grand Canyon using a multi - frequency acoustic system . In Proceedings of the 10th International Symposium on River Sedimentation, Moscow, Russia, vol. 3, 330 – 39

U.S. Environmental Protection Agency, 2015, Gold King Mine—Watershed fact sheet, accessed January 19, 2016 at http://www.epa.gov/sites/production/files/2015-08/documents/goldkingminewatershedfactsheetbackground.pdf.

U.S. Environmental Protection Agency, 2016, Emergency response to August 2015 release from Gold King Mine, accessed January 19, 2016 at http://www.epa.gov/goldkingmine.

U.S. Geological Survey, 2007a, Chapter A: Summary and conclusions from investigation of the effects of historical mining in the Animas River watershed, San Jan County, Colorado, *in* Church, S.E., von Guerard, Paul, and Finger, S.E., eds., 2007, Integrated investigations of environmental effects of historical mining in the Animas River watershed, San Juan County, Colorado: U.S. Geological Survey Professional Paper 1651, 1,096 p. plus CD-ROM.

ED_004888_00001077-00012

U.S. Geological Survey, 2007b, Facing tomorrow's challenges—U.S. Geological Survey science in the decade 2007–2017: U.S. Geological Survey Circular 1309, x + 70 p.

U.S. Geological Survey, 2016, USGS water-quality data and activities for the 2015 Gold King Mine Release, accessed January 19, 2016 at http://water.usgs.gov/owq/gkm/.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A10, available online at http://pubs.water.usgs.gov/twri9A.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at http://pubs.water.usgs.gov/tm1d3.

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