ecology and environment, inc.
Global Environmental Specialists
720 Third Avenue, Suite 1700
Seattle, Washington 98104
Tel: (206) 624-9537, Fax: (206) 621-9832

September 23, 2013

Mr. Michael McCrum
Bureau of Land Management
Alaska State Office
222 West 7th Avenue, #13
Anchorage, Alaska 99513

Re: Bench-Scale Solidification Treatability Study Work Plan
Red Devil Mine Site –Red Devil, Alaska

Dear Mr. McCrum:

As tasked by the Bureau of Land Management (BLM), Ecology and Environment, Inc. (E & E) has developed this letter work plan for conducting a pilot test to determine the effectiveness of solidifying arsenic-contaminated mine tailings at the Red Devil Mine (RDM) site located in Red Devil, Alaska. The following methodology for conducting the pilot test identifies the procedures that E & E will utilize to obtain the solidification data for incorporation into the revised Red Devil Mine Feasibility Study (FS).

INTRODUCTION

A total of four (4) representative soil samples from the RDM site were collected by BLM personnel on September 3, 2013. The attached Figure 1 presents the approximate sampling locations. These four soil samples will undergo grain size analysis (ASTM-D422-63[2007]) and bulk density testing (ASTM D5057-10). The grain size analysis will be performed by TestAmerica's Burlington, Vermont laboratory, and the bulk density testing will be performed by TestAmerica's University Park, Illinois laboratory. The sieve and laboratory analysis will provide information that can be used to decide whether mechanical separation can be utilized to reduce the amount of soil that will be required to be solidified, as well as to finalize the solidification mixes.

In addition to grain size analysis, soil from each of the four locations will undergo total arsenic analysis (EPA 6010B). Based on the analytical results, the location having the highest detected concentration of total arsenic will be selected for use in the solidification testing.

Because there are no standard (e.g., EPA, ASTM) test methods for solidification treatability studies, EPA's *Guide for Conducting Treatability Studies under CERCLA-Final* (October 1992) and *Arsenic Treatment Technologies for Soil, Waste, and Water* (September 2002), as

well as *Chemical Fixation and Solidification of Hazardous Waste* procedures by Jesse R. Conner were used as guidance documents.

In order to properly develop the specifications for the solidification process at the RDM site, the following list of parameters needs to be determined by the pilot test:

- Curing time;
- Volume increase;
- Estimated cost;
- Heat generation due to chemical reactions;
- Handling characteristics and hazards of reagents;
- Physical strength; and
- Leachability.

It is assumed that the solidified soil shall be well coated with the solidification agent so as to pass toxicity characteristic leaching procedure (TCLP) arsenic requirements and have a granular texture suitable for handling by conventional earth-moving equipment. It is not the intent of the pilot test to develop and/or use a solidification mix that will result in the creation of a single solid mass, but rather a granular-type mix.

SOLIDIFICATION MIXES

Based upon our literature review, E & E has determined that portland cement is the most readily available solidification agent in Alaska. Additionally, our literature review indicates that when given a choice between ordinary portland cement (OPC), fly ash, lime, and blast furnace slag, OPC typically has the lowest leachability. Therefore, these other binding agents were not selected. With OPC being the main binding reagent, it is anticipated that the cement mix ratio (MR) will be in the range of 15 to 20% by weight.

While OPC will be used as the main binding agent, E & E's review identified an additive that may enhance the solidification process. Iron salts have a strong affinity for arsenic, and the use of ferrous sulfate to treat arsenic in aqueous waste streams is well documented. Ferrous sulfate has also been used in remediating sites with arsenic contamination in soil. Given that ferrous sulfate can be procured readily (ships in 1-ton bags), and the cost (~$250/ton) is reasonable, it was selected for use as an additive in the pilot test. It is anticipated that the ferrous sulfate molar ratio will be in the range 5:1 to 2:1. It should be noted that the MR for ferrous sulfate is slightly different than that for OPC. The MR for ferrous sulfate is a molar ratio, and is further defined below.

According to previous studies, the optimal water-to-cement ratio for immobilizing metals in soil is approximately 0.40 by weight for OPC. The weight of water within the soil is also included in this amount. Therefore, it is necessary to know the percent moisture content of the

soil. Once the soil moisture is known, each mix shall be prepared using various water/cement ratios (i.e., 0.50, 0.40, 0.30, 0.20) until the desired handling properties are achieved. As part of the total arsenic analysis, percent soil moisture will be determined. The samples that visually appear to have the required handling characteristics shall be retained for the evaluation period and submitted for analysis.

SAMPLE PREPARATION

E & E has developed the following procedures for preparing solidified soil samples. By utilizing these procedures, E & E will be able to accumulate pertinent data for evaluating the use of solidification at the RDM site. The sample preparation will be as follows:

1.) The proportion of soil to be solidified (minimum weight 500 grams) will be weighed. It should be noted that there may be fairly large tailings pieces (>2 inches) in the site samples. For the solidification pilot studies, tailings greater than 1 inch will be removed. It is believed that the majority of leachable arsenic is emanating from the mine tailing fines. The solidification of the fine materials should lead to the greatest reduction in leachability.

2.) The soil will be placed into a 2,000-milliliter (ml) jar. The jar will have a heavy wall, a flat bottom, straight sides, and no lip. The jar will also be translucent, so that the waste level can be observed from the outside.

3.) The soil will be leveled in the jar bottom without void space, and the soil level will be marked on the outside of the jar. After treatment and compaction of the mixture, the level shall be re-marked. The two markings can then be used to determine the approximate volume increase due to the solidification process.

4.) The amount of fixation reagent that is to be utilized will be weighed. For OPC, the amount should be based on the weight of soil and the design MR, which is defined as:

$$MR = \frac{\text{Weight of reagent}}{\text{Weight of soil}}$$

For ferrous sulfate, a molar ratio is used:

$$MR = \frac{\text{Moles of ferrous sulfate}}{\text{Moles of arsenic}}$$

5.) Based on the percent moisture content of the soil, the amount of water to be added will be determined prior to the sample preparation. A graduated cylinder will be used to measure the volume of the water addition. It should be noted that soil that has not been dried will be used in the sample preparation.

6.) The solidification reagent and water will be added to the soil and mixed. Mixing will be conducted using a wide-blade, fairly stiff, stainless-steel spatula. Mixing action depends on the waste and reagents used, and will range from a stirring action to cutting and scraping. While the overall time required is dependent upon the solidification mix, the samples will be mixed for a minimum of 5 minutes.

7.) During and after mixing, observations will be made concerning the difficulty of mixing, appearance, viscosity, presence of excess fluid, color or odor changes, and heat or gas evolution. The pH and temperature of the mix shall be taken at the 0, 2.5-, and 5-minute points during mixing. The pH shall be recorded to the nearest whole pH unit and the temperature to the nearest degree Fahrenheit.

If the sample is still fairly fluid after mixing, it may be compacted by tapping the jar sharply on the work surface. This will also remove most large voids and air bubbles. Tapping will be kept to a minimum to prevent fluid accumulation on top of the sample and the creation of a solid mass.

Once the samples have been prepared, they will be stored under ambient conditions upon the work bench and evaluated for a period of 7 days prior to being submitted to the laboratory for TCLP arsenic analysis.

EVALUATION

The samples shall be evaluated after one, three, and seven days prior to shipment to the laboratory. With a pocket penetrometer, the samples shall be tested for hardness/structural strength. The hardness of the solidified mass should be a minimum of 1 ton per square foot (ton/ft^2). The samples will also be visually inspected to determine changes in consistency and appearance.

After seven days of curing, the level of the sample in the jar will be recorded again to determine additional changes in volume. The samples will then be shipped to TestAmerica in University Park, Illinois for the TCLP arsenic analysis. Upon receipt of the analytical data, E & E will prepare a short letter report of the findings with recommendations. Assuming that the results are favorable (i.e., arsenic passes TCLP), E & E will specify the information needed to develop a full-scale design and implement a sitewide remedy for inclusion in the FS report. An order-of-magnitude cost estimate for implementing solidification will also be provided should it be determined that the technology is viable.

If you should have any questions or comments about the information presented herein, please do not hesitate to contact me at (312) 578-9243 (e-mail at nbrown@ene.com) or Bill Richards at (206) 624-9537 (e-mail: wrichards@ene.com).

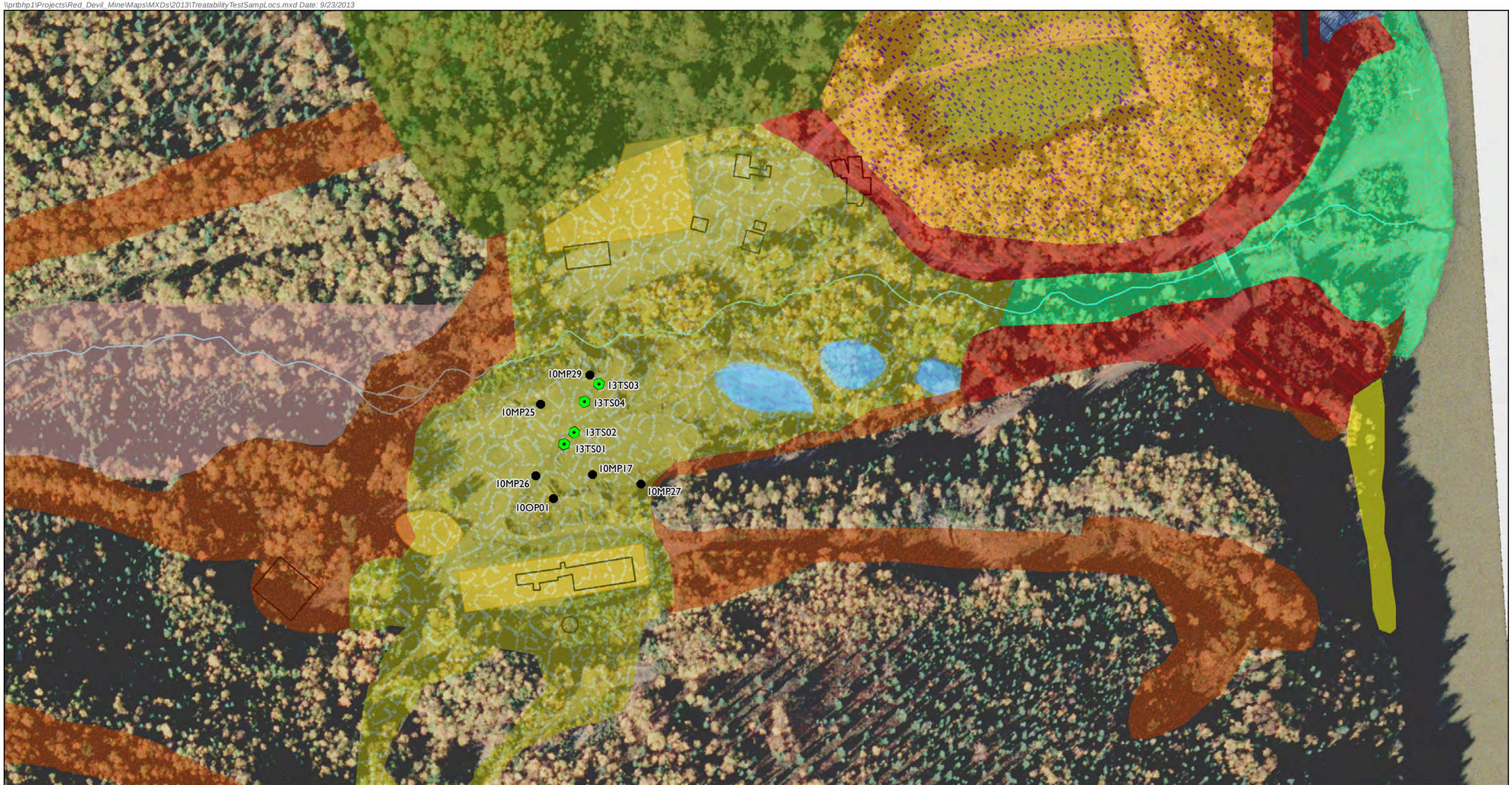
Sincerely,

ECOLOGY AND ENVIRONMENT, INC.

Neil J. Brown, P.E.
Treatability Study Project Manager

cc: W. Richards (E & E)

Attachment:
Figure 1, Treatment Test Sample Locations



- Treatability Test Sample Locations
- RI Surface Soil Samples Exceeding TCLP Arsenic Limit
- Settling Pond
- Monofill
- Historical Structure
- Red Devil Creek alluvial deposits
- Kuskokwim River alluvial deposits
- Loess and/or disturbed loess mixed with soil derived from the Kuskokwim Group
- Disturbed soils in surface mined area (includes areas of undisturbed native soils)
- Mixed loess, Kuskokwim Group bedrock, and Kuskokwim Group derived soils found in the Dolly and Rice Sluices
- Disturbed native soils
- Sluiced overburden
- Tailings and/or waste rock
- Flotation tailings
- Disturbed native soil with local tailings and/or waste rock and fill along road alignments and other areas of operations
- Mixed Red Devil Creek alluvium, native soil, and tailings and/or waste rock

RED DEVIL MINE

Red Devil, Alaska

Figure 1
Treatability Test Sample Locations
Main Processing Area

0 37.5 75 150 225
Feet
0 10 20 40 60 80
Meters

Image Source: Aero-Metric, Inc. 2010a