# SOIL WASHING REMEDIAL ALTERNATIVE SCREENING TECHNICAL MEMORANDUM FOR USS LEAD OU1 ZONE 1 SITE EAST CHICAGO, INDIANA

**Prepared for**
**U.S. Environmental Protection Agency**
**Region 5**
**77 West Jackson**
**Chicago, Illinois 60604**

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## ACRONYMS

| | |
|---|---|
| ARAR | Applicable or relevant and appropriate requirement |
| bgs | Below ground surface |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| COC | Chemical of concern |
| EDTA | Ethylenediaminetetraacetic acid |
| EPA | U.S. Environmental Protection Agency |
| FS | Feasibility study |
| GRA | General response action |
| HCl | Hydrochloric acid |
| HHRA | Human health risk assessment |
| mg/kg | Milligram per kilogram |
| NA | Not applicable |
| O&M | Operation and maintenance |
| OU | Operable Unit |
| PAH | Polycyclic aromatic hydrocarbons |
| RAC2 | Remedial Action Contract No. EP-S5-06-02 |
| RAO | Remedial action objective |
| RAL | Removal action level |
| RCRA | Resource Conservation and Recovery Act |
| RI | Remedial investigation |
| TCLP | Toxicity characteristic leaching procedure |

# 1.0 INTRODUCTION

SulTRAC prepared this soil washing technology assessment for the U.S. Environmental Protection Agency (EPA) under EPA Remedial Action Contract No. EP-S5-06-02 (RAC 2), Work Assignment No. 315-RICO-053J. Under this work assignment, the EPA tasked SulTRAC to prepare a technology assessment presenting the applicability and effectiveness of soil washing as a viable remedial option to address soil impacted by elevated levels of lead and arsenic in USS Lead Operable Unit 1 (OU1) Zone 1. SulTRAC prepared this technology assessment in accordance with the EPA Guidance for Conducting Remedial Investigations and Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA 1988).

The primary goals of the remedial alternative screening evaluation are to (1) discuss soil washing methods and technology, and (2) assess the applicability, effectiveness, and cost of soil washing methods and technology for the site. The purpose of this technical memorandum is to screen soil washing technology and process options, and determine if a remedial alternative with soil washing is suitable for further detailed evaluation with respect to EPA's established evaluation criteria (EPA 1988).

The report is organized into three major sections. Section 1.0 provides a summary of historical activities that have occurred at the site. Section 2.0 discusses the methodology and technology of soil washing technology. Section 3.0 provides the screening of soil washing technology at the USS Lead Zone 1 OU1 site. References are located in Section 5.0. Attachments are located after Section 5.0.

## 1.1 SITE BACKGROUND

SulTRAC completed a feasibility study (FS) in 2012 for all of USS Lead OU1, encompassing Zones 1, 2, and 3. The 2012 FS evaluated a range of technologies and remedial alternatives to address elevated levels of lead and arsenic in soils, including soil washing. All remedial alternatives were evaluated assuming future land use would remain residential. Soil washing was eliminated in the 2012 FS during screening of remedial alternatives prior to a detailed evaluation.

In 2016, the East Chicago Housing Authority announced its intent to close and demolish the West Calumet Housing Complex within Zone 1. Because of the closure of the complex, EPA will be reevaluating the remedy chosen in the 2012 ROD for both the West Calumet Housing Complex and the adjacent park within OU1 Zone 1. The closing of the public housing and city park north of the complex may change the future land use of the site, and potential alternatives should be developed and evaluated for a possible ROD Amendment.

## 1.2 SITE HISTORY

The Anaconda Lead Products and International Lead Refining Company pre-dated the park and housing complex from the early 20th century until the early 1970's. Anaconda Lead Products was a manufacturer of white lead and zinc oxide, and the International Lead Refining Company was a metal-refining facility. These facilities contained a pulverizing mill, white-lead storage areas, a chemical laboratory, a machine shop, a zinc-oxide experimental unit building and plant, a silver refinery, a lead refinery, a baghouse, and other miscellaneous buildings and processing areas (SulTRAC 2012b). The property was developed into the West Calumet Housing Complex and park in the 1970s and was used for multi-family, low-income housing and recreation until 2017. Extensive sampling and removal of shallow soils within and around the site has been ongoing since 2003. The West Calumet Housing Complex will be demolished and all hard surfaces above grade removed from the site in 2018.

## 1.3 NATURE AND EXTENT OF CONTAMINATION

The lateral extent of lead-impacted soil includes all of OU1. Depth of contamination varies, but is prevalent in the top 2 feet of soil. The highest arsenic and lead concentrations throughout all of OU1 were found in the East Chicago Housing Authority Complex with an average concentration of 3,900 mg/kg. The high average concentration may possibly be related to the historical operations at the Anaconda Copper Company facility. Evaluation of the TCLP results, based on lead concentration, suggests that soil containing more than about 2,000 mg/kg lead could be characterized as hazardous waste based on toxicity characteristics (SulTRAC 2017).

Surface soil is a loose black to greyish-brown silty sand. (SulTRAC 2012a). According to the Unified Soil Classification System, silty sand contains a minimum 12% silt and a minimum of 50% sand. Topsoil in the USS Lead OU1 Zone 1 area also includes organic matter and sporadic fill material comprised of silty sand. Fill material mixed with slag and construction debris is found below the surface soils at locations throughout Zone 1.

Lead and arsenic impact in the Zone 1 soils is from a combination of atmospheric deposition from nearby sources as well as on site handling of lead and arsenic during operations at the former Anaconda Copper Company facility. Lead and arsenic deposited from the atmosphere is absorbed on to fine soil particles as was some of the lead and arsenic generated at the former Anaconda Copper Company facility. The facility also generated smelter by-product material, such as slag, that is intermixed with the soil particles but physically separate (ATSDR 2007).

In 2017, Amereco, a consultant to the East Chicago Housing Authority, collected 49 soil samples from 38 locations. Soil borings were advanced using direct-push methods to a depth of 4 to 12 feet bgs. Lead and arsenic were detected in both surface and subsurface soils at concentrations as high as 45,000 mg/kg and 5,200 mg/kg, respectively. Slag and fill material was visually identified to a depth of 11 feet bgs. (Amereco 2017).

# 2.0 DISCUSSION OF SOIL WASHING REMEDIAL TECHNOLOGY AND PROCESS OPTIONS

This section presents a more thorough discussion various soil washing technologies introduced and screened in the 2012 FS.

## 2.1 INTRODUCTION

The RALs were identified in SulTRAC's 2012 FS and were selected on the basis of the results of the HHRA, the evaluation of the expected exposures and associated risks for each alternative, and on the exposure to contaminated soils (EPA 1988). Together the ARARs, RAOs, and RALs create the site-specific "regulatory" framework for the remedial action, and hence, the final remedy to meet. The proposed RAO for OU1 Zone 1 is to **reduce to acceptable levels human health risk exposure to contaminants of concern (COCs) in impacted surface and subsurface soils, through ingestion, direct contact, or inhalation exposure pathways, assuming reasonably anticipated future land-use scenarios.**

The RAL for lead and arsenic was established in the 2012 FS. The RAL for lead in OU1 Zone 1 is 400 mg/kg for residential areas and 800 mg/kg for industrial/commercial areas. The RAL for arsenic at OU1 Zone 1 is 26 mg/kg for both residential and industrial/commercial areas. For the full methodology of the proposed arsenic RAL determination, see Section 2.4.2 of the 2012 FS Report (SulTRAC 2012b).

## 2.2 SOIL WASHING TECHNOLOGY

Soil washing is a water based process for scrubbing soils ex situ to remove various contaminants and minimize the volume of contaminated material. The basic process consists of mixing the contaminated soil with a fluid in a vessel to physically and/or chemically separate the contaminants from the bulk material. Due to the different characteristics of heavy metals and other pollutants, extracting solutions are typically introduced to the separation process. Several options for chemical additions include: surfactants, organic acids, alkalis, complexants, and other solvents (CL: AIRE 2007).

To achieve efficient soil washing, it is recommended that the soil makeup contain predominately coarse material. Typically soil makeup containing more than 30% silt, clay, or organic matter will be inefficient in removing contaminants as clay and silts have a higher metal retaining capacity. Soil characterized from Zone 1 OU1 ranges from 50 to 90% sand and 10 to 50% silt and clay. Topsoil from Zone 1 OU1 is comprised of organic material and silty sand. Due to the OU1 soil composition, the efficiency of soil removal is difficult to predict since the varying silt and clay composition may be inappropriate for soil washing.

When considering the type of applicable soil washing method, it is necessary to determine the association of the contaminant to the soil particle. Contaminants can be absorbed onto a preferred soil particle, separately dispersed alongside soil particles, coat pore walls, or contaminate the soil particle internally (CL:AIRE 2007). The characteristics of how the contaminant is attached to the soil particles is major driving factor in determining cost and efficiency. Discrete contaminant particles occur as individual particles separate from the soil such as battery casings and casing chips which allow for an efficient soil washing process. However, contaminants that are chemically adsorbed onto the soil particle may require additional washing cycles and chemical agents.

Adsorption is the tendency of a chemical to bind to the surface of the soil particles via chemical reactions between the contaminant and the soil particle surface. Adsorption is quantified by the distribution coefficient ($K_d$), chemicals with higher $K_d$ values are more likely to sorb onto soils and sediments while chemicals with lower $K_d$values are more likely to be mobilized by groundwater or surface waters. Lead has a high $K_d$ value ranging from 1,950 to 10,760 which implies lead will adsorb tightly to the soil, thus making is difficult to achieve an efficient separation between lead and the soil particle (SulTRAC 2012a). However, arsenic has a $K_d$ value ranging from 0.28 to 6.46 and has a higher aqueous solubility. This can be an issue regarding water treatment of the washing fluid; the treatment process will need to address the arsenic in the fluid which adds to the complexity and cost of treatment.

Surface soil chemistry conditions, like pH, is another key factor when determining the strength of sorption onto the soil particles. Sorption is greatest between inorganic cations, like lead, and soil with neutral or alkaline pH. Clays, metal oxides, and hydroxides have more negatively charged ions which bind to the positively charged ions such as lead. Previous lab analysis of samples taken at OU1 and the Natural Resources Conservation Service (NRCS) Web Soil Survey data base shows soils in OU1 contain a pH range from 6.5 to 8.3; this indicates sorption for lead is greatest in soils present at OU1 (SulTRAC 2012a).

The OU1 soil composition and the binding relationship between lead, arsenic, and the soil particles raise concern in determining separation efficiency as the silt and clay content varies in the appropriate soil content. In addition, there is an increased risk of exposing the public to contaminated stockpiles during ex situ remedial activities. Potential migration pathways from stockpiled soils includes redeposition by wind and surface water runoff. Chemicals with high distribution coefficients, such as lead and arsenic, are more likely to sorb to soils and be transported along with the particulates. Windborne dust is a primary pathway for contaminants to be released in the atmosphere; this can occur during stockpiling activities and loading soils into the soil washing unit. Surface runoff is significant pathway that can erode surface soils and transport particles via overland flow. Surface water can transport contaminant sorbed particles laterally through runoff or downward through percolation. This risk is increased during storm events, if stormwater runoff flow is sufficient, contaminated soil particulates may be entrained in the surface runoff and be transported to areas that are not paved or vegetated.

Types of soil washing plants include permanent and mobile. Depending on cost and location, a mobile soil washing system may be more cost effective despite the high capital cost. A large factor to consider when deciding between a permanent or mobile system is the amount of space available for a mobile plant; on average, a 20 ton per hour plant can be sited on approximately on half acre (Hubler and Metz). Mobile soil washing plants are more common since permanent soil washing plants have high associated transportation costs as permanent soil washing plants are rare in the United States.

## 2.3 PHYSICAL SEPARATION

Physical separation is typically completed by dissolving or suspending contaminants in a wash solution with a reagent or concentrating the solids and removing the contaminants by attrition scrubbing. Successful physical separation is dependent on the type of contaminant association with the soil particle. Physical separation is favorable towards discrete contaminants comingled with the soil particles. Coarse and oversized material will be removed via screening, jigging, or hydrocycloning (Battelle 1991). To achieve particle size separation, water is introduced as the washing fluid and mixed with the contaminated soil; the slurry mixture is placed in a tumbling mixing vessel which separates the soil based on particle size (FRTR). Particle sizes that allow for the most efficient soil washing range from 0.25 to 2 mm. Surfactants may be added to prevent redeposition onto larger particles. Screens and hydraulic separators separate particles by size and specific gravity, effectively separating contaminants into a smaller volume that can be further treated (Attachment A). Gravity separation is effective in removing high or low specific gravity particles such as lead and arsenic when the COCs are dispersed separately throughout the soil. However, hydraulic classifiers are generally limited to the recovery of particles larger than 50 um. Smaller particles remain in the recycled water and would require additional separation techniques such as filtration or flotation. (Battelle 1991).

A study performed by BESCORP tested the process efficiency for 2mm sand particles via physical separation. The removal efficiency after cycle 1 was 61% and required additional cycles. Two additional cycles were performed and the removal efficiencies were 91%, and 85%, respectively (EPA 1995). This implies several cycles will be required if physical separation is applied to OU1 which will decrease cost effectiveness.

Attrition scrubbing removes contaminant films from coarser particles such as sand but produces finer particles while the larger fraction can be recycled to the site. This process is more effective when separating organics, such as polycyclic aromatic hydrocarbons (PAHs) from soils. Attrition scrubbers produce a high shear environment which particles will scrub against themselves and remove the contaminant by friction.

The typical cost of soil washing by physical separation ranges from $50 to $165 per ton. This is mainly attributed to the type of binding between the COC and soil particle; discrete contaminant particles allow for a more efficient soil washing process. Physical separation will not be an effective option for soils located at the OU1 Zone 1 site as the soil-contaminant association is a chemically bound to the soil particle and will require chemical additions.

## 2.4 CHEMICAL SEPARATION

Chemical separation removes the contaminants from the soil particle to the wash water. To ensure components of the soil are not dissolved with the contaminants, the pH of the water may be changed, chelating agents are added to solubilize the inorganic contaminants, and surfactants are added to solubilize hydrocarbons. A treatability base study would be required to determine the cost and efficiency of lead recovery. Like the physical separation process, water is introduced to the contaminated soil in addition to chelating agents, surfactants, organic acids, alkalis, or solvents depending on the contaminant. The chemical extractant is introduced to the contaminated soil in an extraction unit separate from the mixing unit. Research has shown that Ethylenediaminetetraacetic acid (EDTA) and Hydrochloric acid (HCL) are effective acids for lead separation and can produce an 80% to 90% removal efficiency under proper conditions (Karithika 2016). However, the amount of cycles necessary to reach a high efficiency was not revealed in this study. An acceptable removal efficiency varies on the soil type, extractant concentration, and residence time and can depend on several cycles. The soil-extractant mixture is continuously pumped out of the mixing tank and the soil and extractant are separated by hydroclones. Once extraction is complete, the solids run through a rinse system to remove remaining acids and metals.

Precipitants and flocculent are introduced to the recycled extractant solution to remove the metals via settling and reform the acid and regenerate the solution (Attachment B) (FRTR). The settled material may be processed further to retrieve lead and arsenic for repurpose. Due to the slag and lead-containing dust waste materials found on site, efficient lead recovery for resale may be unachievable due to type of processed lead. Soil washing is not capable of retrieving lead from slag. Prior to backfilling with the processed soil, a soil neutralization process may be required to ensure the placed soil does not contain a low pH due to the soil washing process.

To accomplish efficient lead recovery from soil particles and slag, it would require an additional separation process such as a leaching (Attachment C). However, the alternative to retrieving lead from the settled material is disposal. Although soil washing is a volume reducing remedy, the process produces a concentrated contaminated sludge that will still require disposal. If the processed soil is to be re-used, residual acids in the treated soil must be neutralized prior to re-use. Once the project is complete, the water used in the soil washing system will need to be properly treated and disposed of; a specialized water treatment process would be implemented to address the chemical additives, which can be difficult and expensive. Although EDTA and HCl have been proven to act as an efficient chemical additive, there are concerns regarding the low biodegradability of EDTA, thus its high persistence in the environment. In addition, there have been concerns of the high acute toxic effect of HCl which also raises concern of the risk associated with improper groundwater treatment and disposal (Karthika 2016).

The average cost of chemical soil washing can range between $234 to $390 per ton, including inflation from 1996 levels (EPA 1996). This cost range factors in the cost of chemical additions, the possibility of several soil washing cycles, and water treatment.

# 3.0 SCREENING OF SOIL WASHING REMEDIAL ALTERNATIVE

This section discusses the soil washing as a remedial alternative relevant to the Zone 1 area and screens soil washing remedial option for the existing conditions and potential future land uses.

## 3.1 REMEDIAL ALTERNATIVE DEVELOPMENT

Remedial alternatives for soil must address the potential for ingestion, direct contact, and inhalation risks to site users. The following sections discuss the remedial alternatives identified based on the technologies that have passed screening for the study area. Soil treatment would be conducted at the former West Calumet Housing Complex site. The top two feet of material would be removed to the residential RAL and treated using soil washing technologies. Treated soil would be used for back fill below 12 inches. Topsoil would be imported for the top 12 inches. Lead separated and recovered may be resold for industrial or commercial use. Based on the average concentration of lead in the OU1 Zone 1 soils (3,900 mg/kg), the potential range of recoverable metals is approximately 1,600 tons. The market rate for lead in May 2018 is approximately $2,400/Ton (Business Insider), yielding a value of $2,200,000. Further study is required to evaluate potential market value of this material based on quality, quantity, and location of end user.

The following remedial alternatives will be screened for the Zone 1 site:

- Soil Washing, Physical Separation – This technology alternative involves excavation of approximately 262,350 cubic yards of the material, followed by backfilling to grade with washed soil and imported topsoil and restoring with sod or seed material. *Ex-situ* treatment includes soil washing to recover lead via physical separation. Treated soil will be sampled to ensure contaminant concentrations are below residential RALs and placed back as fill material. Water used in the soil washing treatment process will require treatment prior to proper disposal.
- Soil Washing, Chemical Separation - This technology alternative involves excavation of approximately 262,350 cubic yards of the material, followed by backfilling to grade with washed soil and imported topsoil and restoring with sod or seed material. *Ex-situ* treatment includes soil washing to recover lead via chemical separation. Excavated soil will be go through soil washing to recover lead via chemical and physical separation. Treated soil will be sampled to ensure contaminant concentrations are below residential RALs and placed back as fill material. Water used in the soil washing treatment process will require treatment prior to proper disposal..

## 3.2 REMEDIAL ALTERNATIVE SCREENING

SulTRAC screened the potential soil washing remedial alternatives identified above against three broad criteria: short- and long-term effectiveness, implementability (including technical and administrative feasibility), and relative cost (capital and O&M) in accordance with EPA guidance. The purpose of the screening evaluation is to identify viable alternatives for a more thorough and extensive analysis, and alternatives will be evaluated more generally during the screening evaluation than during the detailed analysis (EPA 1988).

In evaluating effectiveness, the “short-term” is considered to be the remedial construction and implementation period, while “long-term” begins once the remedial action is complete and RAOs have been met (EPA 1989). Technical feasibility includes the ability to construct, reliably operate, and meet regulations, as well as the ability to meet the O&M, replacement, and monitoring requirements after completion of the remedial action (EPA 1989). Administrative feasibility includes the ability to obtain approvals from other agencies; the availability of treatment, storage, and disposal services; and the availability of equipment and technical expertise (EPA 1989). The objective of the cost evaluation is to eliminate from further consideration those alternatives whose costs are grossly excessive for the effectiveness they provide. Cost estimates for alternatives should be sufficiently accurate to continue to support resulting decisions when their accuracy improves beyond the screening level. The cost in the streamlined screening of alternatives evaluates the capital and O&M costs on a relative basis (EPA 1989). Table 3-1 lists the capital and O&M costs for each alternative in comparison to traditional transportation and disposal costs.

Since a significant percentage of the lead is absorbed on the soil, physical separation will not be effective to remove lead and arsenic from the soil. The more complex chemical separation process using chemical addition, scrubbing, hydrocyclone separation, and drying shown in Attachment B would be required. As discussed in Section 2.4, this process will generate a significant amount of secondary liquid that will need to be treated and either reused or disposed.

A complete cost estimate for using chemical soil washing for impacted soil in the top 24 inches is shown in Attachment D. This estimate assume 100% of the lead in the soil is recovered and chemical soil washing can be accomplished at the low end of the expected cost range. Treated soil can be used as backfill from 6-24 inches. Topsoil would be imported for the top 6 inches since the treated soil will be unsuitable for restoration. Excess treated soil and concrete debris would be disposed off-site. The estimated cost to use chemical soil washing as a remedial alternative is $75,730,000. This cost includes long term operations and maintenance since impacted soil will remain on site below 24 inches.

## TABLE 3-1. REMEDIAL TECHNOLOGY SCREENING SUMMARY

| Alternative | Effectiveness | | Implementability | | Cost | | Retained | |
|---|---|---|---|---|---|---|---|---|
| | Short-Term | Long-Term | Technical | Administrative | Capital | O&M | Yes | No |
| 1. Excavation of all impacted and foreign material in the top 2 feet + *Ex Situ* treatment by soil washing – Physical Separation | A significant percentage of the lead and arsenic is absorbed on the soil particles and would not be removed with physical separation. Silt content between 12-50 % is in the range where soil washing is not effective. On site stockpiling and treatment would increase risk to workers and the public. Significant imported backfill would be required since even treated soils, principally sand, would be unsuitable for sod or seed. | If soil exceeding residential RALs left in place, it will require institutional controls and long-term O&M; would allow land reuse in accordance with cleanup levels; does reduce toxicity, mobility, or volume of some contamination, remaining impacted material will be physically moved to a licensed disposal facility | Requires large area to stockpile and process contaminated soils; recommended pilot test to determine efficiency; utilities, including water and power, are not available at the site after demolition of the housing complex. Increasing excavation depth reduces technical implementability by generating more debris and groundwater. | State and community would need to accept on site treatment of impacted soil. Requires at least 2 years to treat all material, assuming 100 tons/hr 10 hours each day. Significant monitoring requirements likely will be necessary. Appropriate waste manifests and documentation for transportation and disposal purposes | Main capital costs associated with construction of mobile soil washing plant; soil washing; water treatment; hauling and disposal of sludge material. Current cost estimates for physical separation process is $50-165/ton. Significant percentage of material would still require off-site disposal. Additional costs include excavation of impacted soil and backfill of treated soil and imported topsoil. | O&M will not be required if all, impacted material is treated and/or removed from the site | | ✔ |
| 2. Excavation of all impacted and foreign material in the top 2 feet + *Ex Situ* treatment by soil washing – Chemical Separation | A significant percentage of the lead and arsenic is absorbed on the soil particles. Silt content between 12-50 % is in the range where soil washing is not effective. Soil may require multiple wash cycles to remove both lead and arsenic. On site stockpiling and treatment would increase risk to workers and the public. Significant imported backfill would be required since even treated soils, principally sand, would be unsuitable for sod or seed. | If soil exceeding residential RALs left in place, it will require institutional controls and long-term O&M; would allow land reuse in accordance with cleanup levels; does reduce toxicity, mobility, or volume of some contamination, remaining impacted material will be physically moved to a licensed disposal facility | Requires large area to stockpile and process contaminated soils; recommended pilot test to determine efficiency; utilities, including water and power, are not available at the site after demolition of the housing complex, requires acidic chemical additive; produces highly concentrated lead and arsenic sludge that requires further processing to retrieve lead and disposal costs for remaining product; produces complex contaminated water which requires treatment and disposal; requires soil neutralization treatment prior to backfilling activities; produces highly concentrated sludge material that still requires hazardous waste disposal. Increasing excavation depth reduces technical implementability by generating more debris and groundwater. | State and community would need to accept on site treatment of impacted soil. Requires at least 2 years to treat all material, assuming 100 tons/hr 10 hours each day. Significant monitoring requirements likely will be necessary. Appropriate waste manifests and documentation for transportation and disposal purposes | Main capital costs associated with construction of mobile soil washing plant; soil washing; water treatment; hauling and disposal of sludge material Current cost estimates for chemical separation process is $234-390/ton. Additional costs include excavation of impacted soil and backfill of treated soil and imported topsoil. Overall cost estimate for 24 inches of soil using full recovery of lead and low end of chemical soil washing cost is approximately $75,730,000, which is almost three times the cost of Alternative 4B. | O&M will not be required if all, impacted material is treated and/or removed from the site | | ✔ |

# 4.0 CONCLUSION

Although soil washing may be an effective *ex situ* remedial alternative, it is determined that soil washing technology is unsuitable as a remedial option for OU1 Zone 1. A mobile soil washing plant would be placed onsite since permanent soil washing plants are rare and the cost of transportation would not be cost effective. Due to the bonding properties between the COCs and soil particles in OU1, physical separation would not be effective on much of the impacted soil. Chemical separation may be appropriate to achieve successful separation. However, chemical separation requires surfactants such as EDTA or HCl which can be costly and require additional water treatment for proper disposal. If the water treatment process is not performed properly, may cause an increased health risk as EDTA and HCl have a low biodegradability and acute toxic characteristics. The silt content in OU1 Zone 1 soils and tight adsorption properties of lead and arsenic increase the difficulty of achieving efficient soil washing rates; this may require several washing cycles, higher concentrations of chemical additives, and a more rigorous water treatment process. Chemical soil washing conducted at OU1 will most likely cost $234 to $390 per ton while the traditional method of transportation and disposal costs $45 to $95 per ton (SulTRAC 2012b). Treated soil would not entirely meet backfill requirements, so additional topsoil would be required and add to the overall cost. The overall cost to remediate and restore OU1 Zone 1 is approximately $75,730,000, significantly more than the equivalent excavation and off-site disposal alternative.

Although transportation and disposal of all contaminated soils does not include a treatment process, the material will be properly disposed at a RCRA Subtitle D Hazardous-waste landfill with adequate capacity. This option minimizes the public's exposure to the contaminated material. Soil washing may increase the public's exposure to contaminated material by stockpiling and processing activities. The volume of material requiring treatment would take at least 2 years, in addition to excavation and backfill tasks associated with other remedial alternatives evaluated in the FS. Due to the questionable effectiveness, technical and administrative implementation constraints, high capital cost and uncertain value of recoverable material, SulTRAC does not recommend further analysis on *ex situ* soil washing remedies for OU1 Zone 1.

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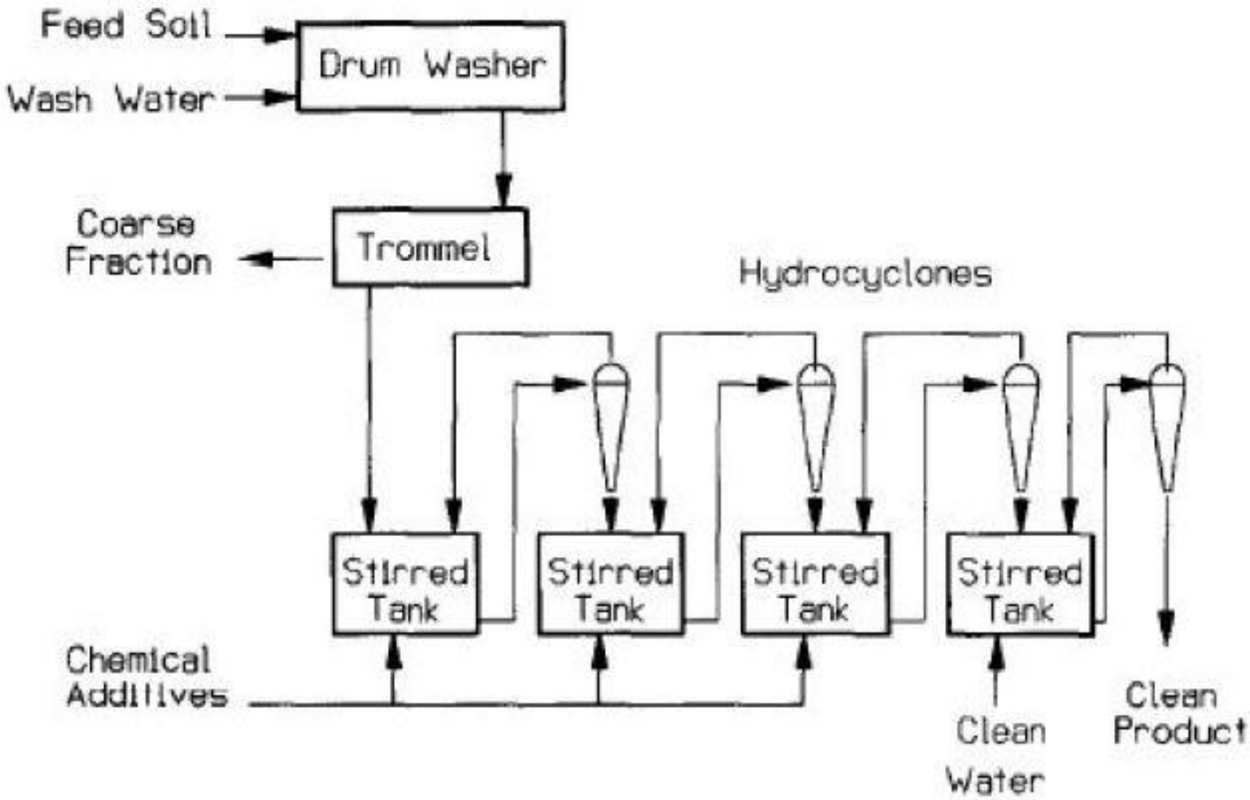
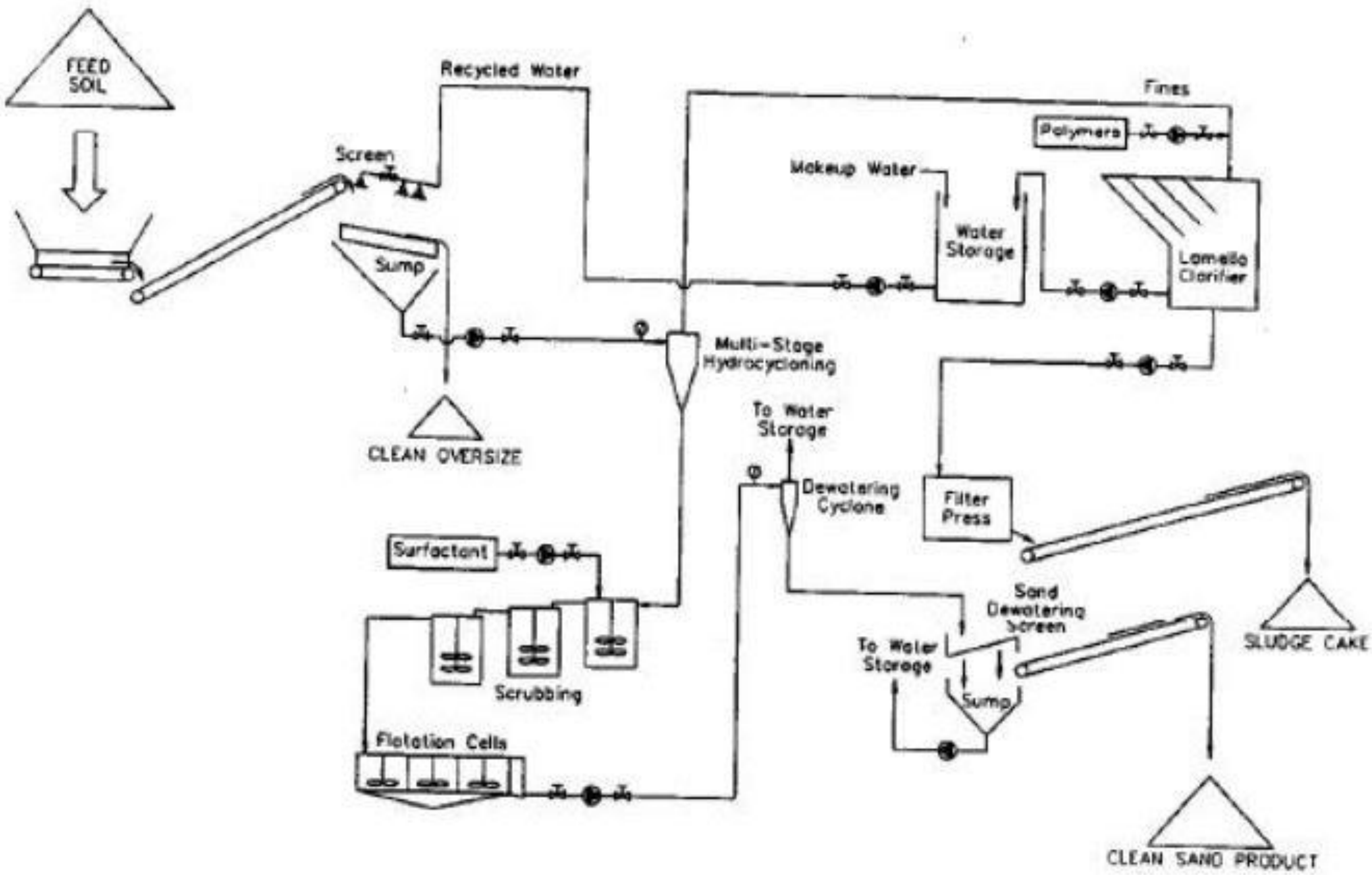
# ATTACHMENTS

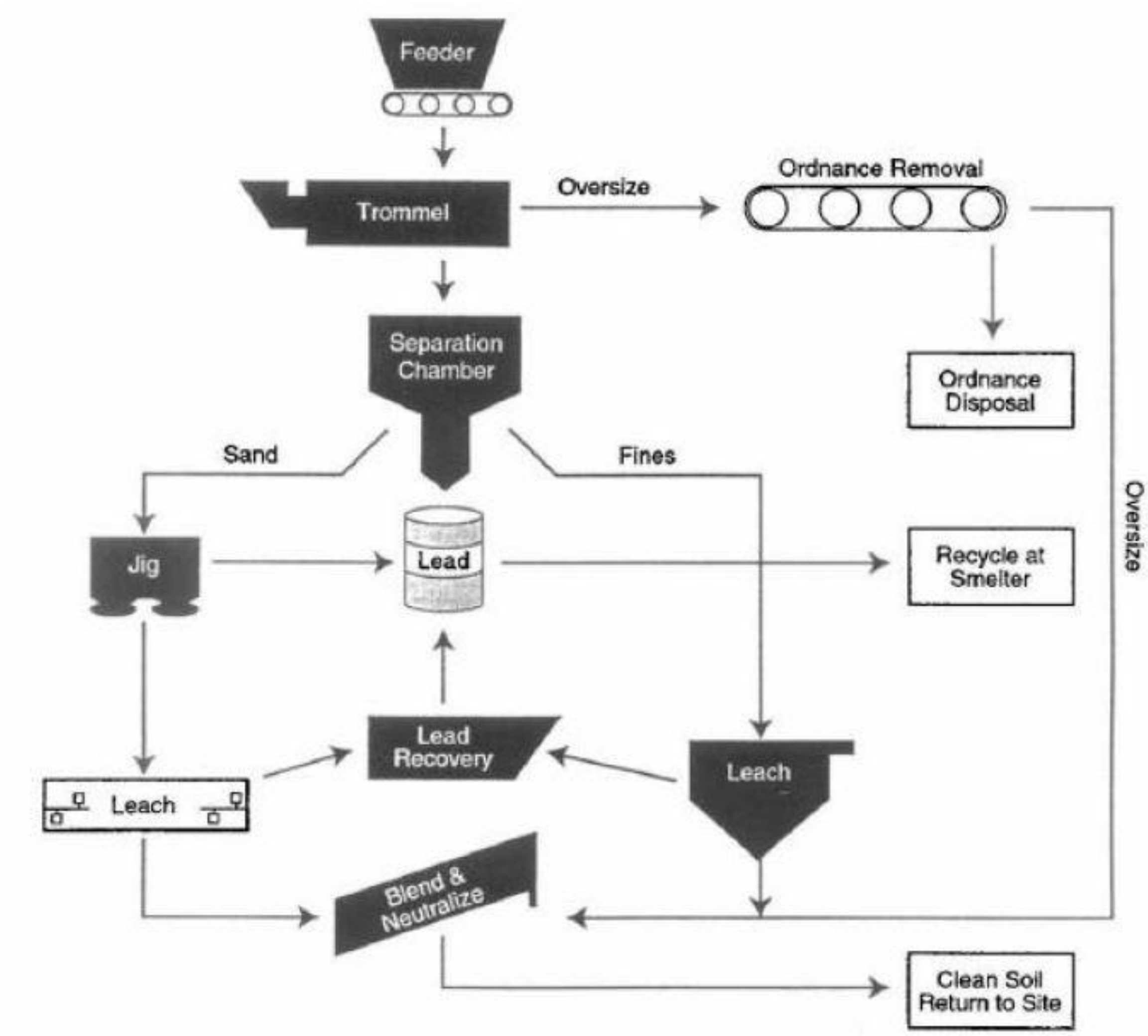
**ATTACHMENT A: MOBILE SOIL WASHING SYSTEM (Hubler and Metz)**



**ATTACHMENT B: SOIL WASHING WITH CHEMICAL SEPARATION PROCESS (Hubler and Metz)**



**ATTACHMENT C: LEACHING PROCESS FOR LEAD RECOVERY (Hubler and Metz)**



**ATTACHMENT D: ALTERNATIVE 6 - CHEMICAL SOIL WASHING COST ESTIMATE**

| CAPITAL COSTS | | | | | |
|---|---|---|---|---|---|
| **Item** | **Description** | **Quantity** | **Unit** | **Unit Price** | **Total Cost** |
| **Preparation** | | | | | |
| 1 | Engineering Design/Agency Approvals/Access Agreements | 1 | Lump | $250,000.00 | $ 250,000 |
| | **Preparation Subtotal** | | | | **$ 250,000** |
| **Implementation** | | | | | |
| 2 | Construction Contractor Mobilization/Demobilization, Site Preparation and Submittals | 1 | Lump | $500,000.00 | $ 500,000 |
| 3 | Excavation and stockpiling of 24 inches of impacted surface material | 157,206 | CY | $ 6.00 | $ 943,234 |
| 4 | Excavation of soil over utility lines | 741 | CY | $ 56.00 | $ 41,496 |
| 5 | Concrete size reduction - excavation of concrete foundations | 5,000 | CY | $ 2.29 | $ 11,450 |
| 6 | Chemcial soil washing of impacted soil | 236,920 | TON | $ 234.00 | $ 55,439,280 |
| 7 | Revenue from recovered lead | 924 | TON | $ (2,400.00) | $ (2,217,571) |
| 8 | Replacement of clean backfill (6 to 24 inches) | 122,210 | CY | $ 8.00 | $ 977,680 |
| 9 | Import and Place topsoil | 40,737 | CY | $ 20.65 | $ 841,212 |
| 10 | Hauling and disposal of non-hazardous material (concrete and excess soil) | 61,105 | TON | $ 45.00 | $ 2,749,725 |
| 11 | Installation of non-woven geotextile liner | 244,420 | SY | $ 1.28 | $ 312,858 |
| 12 | Seeding | 244,420 | SY | $ 0.88 | $ 215,090 |
| | **Implementation Subtotal** | | | | **$ 59,814,454** |
| **Site Restoration** | | | | | |
| 13 | Site Restoration and Cleanup | 1 | Lump | $ 3,000.00 | $ 3,000 |
| 14 | Demobilization | 1 | Lump | $250,000.00 | $ 250,000 |
| | **Site Restoration Subtotal** | | | | **$ 253,000** |
| | | | | | |
| **Construction Subtotal** | | | | | $ 60,317,454 |
| 15 | Construction Contractor Bonds | 2% | | | $ 1,206,349 |
| 16 | Project Management and Construction Oversight | | | | $1,200,000.00 |
| **Construction subtotal plus Contractor Bonds, Project Management, and Oversight** | | | | | **$ 62,723,803** |
| | | | | | |
| **CAPITAL COST SUBTOTAL** | | | | | **$ 62,723,803** |

| INSTITUTIONAL CONTROLS COSTS | | | | | |
|---|---|---|---|---|---|
| **Item** | **Description** | **Quantity** | **Unit** | **Unit Price (Incl. O&P)** | **Total Cost** |
| **Institutional Controls** | | | | | |
| 1 | Prepare LUC Implementation Plan (mid-level staff with senior review) | 100 | hr | $ 110.00 | $ 11,000 |
| 2 | Meetings with agencies (senior staff and attorneys) | 40 | hr | $ 250.00 | $ 10,000 |
| **Institutional Controls Subtotal** | | | | | **$ 21,000** |
| **O&M COSTS** | | | | | |
| **Item** | **Description** | **Quantity** | **Unit** | **Unit Price (Incl. O&P)** | **Total Cost** |
| **Annual Maintenance** | | | | | |
| 1 | Soil cap maintenance (mowing, clearing, repairing erosion damage) | 50.5 | AC | $ 50.00 | $ 2,525 |
| | **Maintenance Subtotal** | | | | **$ 2,525** |
| **Annual Inspections** | | | | | |
| 2 | Annual cap inspections (includes labor - 2 hours per site- and travel) | 8.0 | hr | $ 200.00 | $ 1,600 |
| 3 | Annual inspection report | 1.0 | ls | $ 5,000.00 | $ 5,000 |
| 4 | Project Management | 4.0 | hr | $ 200.00 | $ 800 |
| | **Inspections Subtotal** | | | | **$ 7,400** |
| | | | | | |
| **Annual Operation and Maintenance Subtotal** | | | | | **$ 9,925** |

| ALTERNATIVE 4B - RESIDENTIAL STANDARD | |
|---|---|
| **Description** | **Subtotal** |
| Construction | $ 62,723,803 |
| Institutional Controls | $ 21,000 |
| Operation and Maintenance (30-Year Present Value Analysis Costs) | $ 360,206 |

| | | |
|---|---|---|
| Contingency | 20% | $ 12,621,002 |
| **Total (Rounded)** | | **$ 75,730,000** |