Section 8.0
Technology Implementation

8.1 DoD Need

The Department of Defense established the DERP in 1984 to promote and coordinate efforts for evaluation and remediation of contamination at DoD facilities. Congress established the DERA in 1986 as a part of the SARA. The Army uses the Defense Site Environmental Restoration Tracking System (DSERTS) to manage and track environmental restoration processes at installations. The DSERTS database is the principal source of information for the Environmental Restoration Annual Report to Congress.

DSERTS was used to identify sites that have had lead contamination in soils. The database was screened to eliminate sites where the maximum reported concentrations of lead were less than the USEPA established cleanup levels. Sites that have already been remediated were also screened out. There were a total of 458 sites that have at some time in the past shown lead contamination levels above the residential cleanup levels (400 mg/kg). Of these sites, 319 sites had lead contamination above the industrial cleanup levels (1,000 mg/kg).

Navy and Air Force sites are not included in DSERTS, but the majority of lead contamination should be within Army installations because of the large number of firing ranges and the number of ammunition plants on Army sites. The number for the Army sites will be high since there are some sites that will not be remediated because risk analyses have shown that some of these sites do not pose a risk to human health or to the environment. However, the DSERTS data are an indication of the magnitude of the problem. In the 1999 DSERTS data, there were 889 sites with metals contamination that exceeded the risk-based levels.

Of the 889 sites, there were 450 sites that were scheduled to be cleaned up because of metals contamination. According to a query of the DSERTS database, these 450 sites had approximately 2,285,000 cubic yards of soil that required remediation at an estimated cost of $1,038 million. In addition, there were 2,861 acres that were to be capped or isolated within a fence.

8.2 Transition

Phytoextraction technology does not appear to be practical or economical for implementation *in situ* under the conditions at sites such as TCAAP, and a discussion of some of the problems encountered in the application of the field demonstration is in order before a decision can be made on a proper transition process. The major obstacles to phytoremediation at TCAAP were:

- Variability of soil types
- High precipitation area
- Toxic contaminants
- History of open burn/open detonation - large pieces of debris that induced channeling; compounds toxic to crops.

- Shallow hardpan at Site C which prevented deep rooting and caused water-logging.
- Shallow groundwater

Some of these obstacles are inherent to phytoremediation and some were site-specific to TCAAP. Many of these factors were interrelated and produced problems with plant growth and nutrition from the outset of the demonstration The symptoms were treated but plants did not realize full yield potential and lead uptake capacity. These obstacles have been addressed in the Implementation Plan, Section 8.3.

After the first year demonstration, TVA recognized that it would be difficult to evaluate lead removal from the soil due to the extreme variability in soil lead concentrations across the plot areas. Soil lead variability was complicated by the fact that large quantities of solid debris (burned and unburned wood, rail ties, concrete, scrap metal, etc.) and particulate lead contaminants were found at the site during the initial soil cultivation and planting that was not anticipated from review of the RI/FS and discussions with on-site personnel. Therefore, lead removal in the crop biomass was the only suitable means to evaluate removal of lead from the soil. TVA did not expect to be able to detect a change in soil lead concentration after one year, or possibly even after two years because of the high variability. For phytoextraction to work at such sites, screening of debris and particulates and homogenizing of the soil would be a required step. However, the nature of the debris and particulates would require complete excavation of the contaminated areas, in which case one of the *ex situ* remediation methods would probably be more economical and efficient to use.

In this demonstration, lysimeters were installed to monitor potential EDTA or lead movement through the soil. However, due to the nature of the soil these did not perform consistently. For future studies, a better approach would be a water balance simulation which includes meteorological data and hydraulic conductivity of the soils. Weekly precipitation data collected at the test plots could be used as well as local meteorological data (temperature, wind speed, humidity, etc.) obtained from resources in the vicinity (e.g., NOAA, airports, etc.). Hydraulic conductivity of site soils should be another facet of this technology to enable more accurate estimation of the amounts and the rate of application of soil amendments applied. Because of the heterogeneous texture of the soil at TCAAP, sampling to adequately determine the overall hydraulic conductivity of the sites to perform a mass water balance was impractical and prohibitively expensive. An accurate assessment of the hydraulic conductivity of this site would have required samples to have been taken in close proximity (sample to sample) to account for the varying texture and varying soil infiltration rates.

Unfavorable weather and other environmental factors prevented valid assessment of crop removal of lead during the latter two crops of the demonstration. In the short growing season in the TCAAP area, the cropping scheme and plant species were changed after the 1998 demonstration in order to increase the remediation effectiveness in 1999. Plant density was increased by planting on 15-inch rows in 1999, while corn in 1998 was planted on 30-inch rows. The corn used in 1998 was a field corn variety; in 1999 a silage variety was used to increase biomass yield. However, the variability of soil types and lead concentrations within the sites (more particularly, Site C), the relatively short growing season, and the high concentrations of lead in the soil would likely require many more years than originally anticipated for successful remediation by crops. A complete discussion of the factors involved in calculating the times required for remediation is shown in Section 6.0 The time requirements should be carefully considered before initiating a phytoextraction scheme in under less than ideal conditions.

8.3 Draft Implementation Guidance Document

This document is intended to provide overall guidance for conducting a phytoextraction project in situations where constraints to implementation are minimal and contamination levels are not much above the desired cleanup level. This document does not endorse implementation under conditions of extreme heterogeneity, such as military disposal sites in general, and Site C at TCAAP in particular.

The procedures outlined in this document are based on the results of a two-year demonstration. Some practices, such as crop selection, cultural practices, types of soil amendments, and methods of application, changed after the first year of the demonstration. Therefore, this document is not complete and can only serve as a general guide. Some of the recommendations may still need to be modified for maximum treatment effectiveness. However, the experience of the researchers working under extremely difficult and heterogeneous conditions has resulted in some definite guidelines that, without doubt, should be carefully considered before implementing a phytoextraction project at any given site. Experience has shown that this phytoextraction technology likely will not work *in situ* to maximum effectiveness for removal of lead at sites where open burn/open detonation practices have been followed, such as at Site C at TCAAP. Such sites will usually be poor candidates for growing plants because the soil is likely heavily contaminated with a variety of solid debris, other toxic contaminants and, oftentimes, particulate lead. The solid debris essentially destroys soil structure and proper hydraulic properties. Unless the soil is first excavated, the debris screened out, and the soil made uniform, channeling and preferential flow will render the soil entirely unsuitable for application of chelates which solubilize and thus possibly promote leaching of lead. In addition, unless particulate lead is first removed, it will be impossible to measure any realistic reductions in soil lead through plant uptake.

Even under conditions where lead is present in the ionic form (e.g., battery disposal operations, lead smelters, lead styphnate production facilities), the circumstances may still be less than ideal for the culture of growing plants, and some adjustments to procedure will likely be necessary even after the process has begun. Each contaminated site will be unique with its own set of challenges which may limit or reduce the effectiveness of the technology. The main focus of this technology is to maximize lead concentration in the plants and to maximize biomass production in order to achieve the greatest lead uptake by the crops under the existing conditions. Thus, the flexibility to change and adapt as required is an integral part of the remediation plan. Plant sampling after each harvest will monitor the progress of the remediation and provide a feedback loop to allow for procedural adjustments, as needed.

The general guidelines for implementation of a phytoextraction project are shown below. Definitive recommendations and procedures will, by necessity, be site-specific. These steps must be implemented under the oversight of a professional agronomist or other qualified personnel with a background in soil chemistry, soil fertility, soil taxonomy, and plant science. It is most strongly advised that someone with an agronomic or farm background be responsible for day-to-day field operations and maintenance of the growing crops. This individual would guidance on a regular basis, but should also be able to independently distinguish any abnormalities that might arise during the project and, after discussion with the professional, act to counter such problems.

Under a very specific and narrow range of conditions, phytoextraction may offer the potential as a relatively inexpensive remediation method compared to other technologies. Factors which will directly control the success of the technology may be:

- Soil type
- Soil fertility levels
- Type of lead present in soil
- Potential plant availability of lead in the soil
- Soil lead concentration
- The presence of other contaminants

In addition, there are very few known plant species that may be suitable for this technology. Thus, field demonstrations with a variety of plant species have yet to be implemented. The focus of this project was not to determine or screen plant species for maximum lead uptake. At the time of this writing, the following are being used in field demonstrations for remediation of lead:

- Indian mustard
- White mustard
- Corn
- Sunflower

Crops that may be used to remediate other heavy metals include:

- Amaranthus (radioactive cesium and strontium)
- Sunflower (radionuclides)
- Oat and barley (zinc)
- Alpine pennycress (cadmium)
- Indian mustard (copper and selenium)
- Alyssum species (nickel)

There are certainly other plant species that have the potential to accumulate lead and other metals in their aboveground tissues; these may eventually be categorized by identifying certain basic biochemical pathways for metal metabolism. For now, however, the technology is still in stages of development and refinement, and a comprehensive listing of such plants is not available.

The following list is a detailed, but not necessarily all inclusive, guide to use when undertaking a phytoextraction effort:

1. Planning for utilizing phytoextraction at a specific site will start by obtaining detailed site information from the remedial investigation/feasibility study (RI/FS). The information needed would be the general nature of the site, specific COCs, type and concentration of COCs, climate, geology, hydrogeology, etc.

2. Determine the extent of past site characterization and the extent of future characterization that may be required. Do not rely on the RI/FS to be comprehensive or totally accurate since it may not focus on the site characteristics pertinent to phytoremediation.

3. Obtain a soil characterization for other contaminants present that would inhibit plant growth and prevent the use of phytoextraction methods altogether, e.g., beryllium and thallium.

4. Obtain a soil characterization for chemical and physical properties that affect agronomic suitability for growing plants, e.g., pH, indigenous nutrient levels, cation exchange capacity, organic matter, soil texture, water holding capacity, shallow hardpan, and infiltration rates, etc.

5. Determine the depth to groundwater, direction of flow, rate of flow, and hydraulic properties of the soil.

6. Determine if phytoextraction is suitable based on:

    - Type and concentration of COCs, i.e., contaminant in ionic form and present at a concentration that can be remediated within a reasonable timeframe

    - Depth and extent of COCs, i.e., accessibility of COCs to plant rooting system

    - Other contaminants present, e.g., beryllium or thallium, that might inhibit plant growth and prevent the use of phytoextraction methods altogether

    - Logistics of site, i.e., accessibility to irrigation water, equipment, and personnel

    - Climate suitable for proposed remediation crops, multiple crops/year

    - Geology and hydrogeology, i.e., difficulty in sampling, field preparation, and depth to groundwater

    - Site terrain, i.e., slope, wooded verses open field, presence of rocks/obstructions, etc.

7. Based on the above information, determine if the process can be implemented *in situ*, or if the soil should be excavated, screened, and homogenized, and a liner installed to control movement of solubilized lead.

8. Consult with appropriate regulatory agencies (state, federal, and local if required) as to permitting and legal requirements and obtain clearance to proceed.

9. Conduct intensive soil sampling and comprehensive analyses. Soil sampling should be performed with power sampling equipment to conserve labor and maximize cost-effectiveness. The analyses are conducted to:

   - Determine soil pH. This factor is the single most important soil parameter measured. Soil pH governs both efficiency of nutrient utilization and potential toxicities from elements such as aluminum and manganese. The optimum pH range for most agricultural crops is 6.0-7.0, although crops can tolerate a somewhat lower or higher range. If soil pH is on either side of this range, proper nutrient utilization is greatly reduced and chances of toxicities may be increased. Soil pH also serves as the starting point from which buffer curves are determined in order to calculate the proper application rate of acetic acid.

   - Determine soil texture, i.e., sand, silt, and clay content, which affects cultural practices such as tillage and irrigation; potential leaching, as well as runoff of nutrients and soil amendments; plant rooting depth; and the aeration status of soils. Sandy soils will require supplemental irrigation and nutrients for best crop production. However, the potential for movement from the rooting zone of both of nutrients and EDTA, is greatly increased and shallow root systems may develop from over watering. Sampling difficulty may be greatly increased in rocky, sandy soils. A high clay soil may exhibit poor/reduced infiltration, anaerobic areas after heavy rains, restricted rooting depth, and significant sorption capacity for EDTA which may reduce chelate effectiveness. This, in turn, will increase the amount of chelate required and add to project costs.

   - Determine the nutrient status of the soil for the macronutrients nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur if the soil is sandy and the mineralogy indicates a lack of sulfur-containing minerals. Also, included in these analyses may be the micronutrients copper, iron, manganese, and zinc. These elements are just as essential for proper growth, although required by agronomic crops in very small amounts and at a fraction of the amounts needed for macronutrients.

   - Determine the cation exchange capacity (CEC) and the organic matter content of the soil. The CEC is a measure of the soil attraction, or the strength of attraction, for various cations, whether these be nutrients such as K or a metal such as lead. This parameter may be useful in determining fertilizer recommendations and may influence decisions regarding the amount of EDTA to apply to a given soil. A soil with high CEC will have a strong affinity for metal contaminants. The exchange capacity is also directly related to the buffering capacity (resistance to change in pH) of a soil. Organic matter influences other important chemical and physical properties of the soil, such as fertility, CEC, and moisture-holding capacity. It also affects reactions of inorganic contaminants such as metals and oxyanions, e.g., arsenic and selenium, both before and after amendment additions to soil.

- Map the concentration and distribution of COCs within the proposed remediation area. These analyses are also necessary to (1) establish baseline concentrations of COCs; (2) map concentrations and locations of potentially phytotoxic elements such as Be or Tl; and (3) calculate the amounts of soil amendments needed to remediate the primary COCs (Pb). However, a point for consideration is that there may be significant variability, or heterogeneity, in COCs concentrations across the area, which will result in "hot" and "cold" spots. These areas of higher- or lower-than-average concentration may be anomalies, or may persist throughout the course of the project, and interpretations of data should be made with this factor in mind. Multiple tillings may somewhat even out the concentrations across the field.

10. Perform acetic acid buffer curves on a bulk soil sample, which is a composite of all samples collected across the remediation area. This is done to determine the amount of acetic acid required to reduce the soil pH to 5.5 in order to maximize lead solubilization before adding EDTA. The determination produces a curve which shows in stepwise fashion the amount of pH reduction resulting from each milliequivalent (meq) of acetic acid added per gram (g) of soil. The total amount of acetic acid required to reduce the soil pH to 5.5 is read from this curve.

11. Calculate the amount of acetic acid needed. This is done by converting the proper value of acetic acid obtained from the buffer curve to a pound per acre basis. This amount of acetic acid will be diluted approximately 1:6 with water for application to the field.

12. Determine potentially plant-available forms of lead using a sequential extraction procedure. This method uses progressively stronger extractants to determine various forms of lead in soil, which range from easily extractable (likely to be plant-available) to very resistant (non-available) forms. The procedure fractionates soil lead into water-soluble, exchangeable, carbonate-bound, oxide-bound, organic-bound, and crystalline matrix bound forms of lead. Typically, the first three forms are the most amenable to extraction by a chelate and are thus considered the most plant available. The concentration of lead in these forms will be less than the total soil lead concentration.

13. Calculate the amount of EDTA to add to the soil. This is based on the results of the sequential extraction procedure. The amount of EDTA should be adequate to solubilize sufficient lead across the remediation area for plant uptake while minimizing chelate movement out of the root zone. The ideal amount is a 1:1 molar ratio of EDTA to *plant-available* lead in the soil. However, since Pb concentrations tend to be quite variable in the soil, a 1:1 ratio cannot be consistently achieved across an entire remediation area. Therefore, a practical application rate may be achieved by examining the mean, the median, and the frequency distribution of plant-available lead across the field, then basing the EDTA

application on a rate that provides a 1:1 ratio for 75% of the field. This is a conservative approach which will mean in some areas the chelate is under-applied, while in other areas it will be over-applied, but this minimizes the risk for movement of the lead-EDTA complex out of the rooting zone.

14. Determine suitable warm and cool season crops (within a group previously selected for maximum contaminant uptake) for the area. Professional guidance is essential to this step and selection should be done in consultation with the project technical manager and knowledgeable local or university extension service personnel. Recommendations are made based on the climate, length of growing season, and potential for maximum yield of selected crops. The order of planting will depend on the season when operations commence.

15. Determine fertilizer requirements for the crop. Recommendations of N-P-K will be based on the normal agronomic rate adjusted for the amount of nutrient already present in soil and the crop removal rates for each nutrient. The fertilizer rate then will be adjusted upward in order to maximize vegetative biomass yield. This is done to obtain the greatest removal of contaminants in the plant biomass. Fertilizers typically employed if a corn crop is planted are ammonium nitrate to supply N, triple superphosphate for P, and potassium sulfate (K_2SO_4) or potassium chloride (KCl) for K. For a mustard crop, urea is the preferred N source, but the P and K sources are the same. Sufficient P should be applied to maintain adequate levels in soil for the entire growing season. This is particularly important since a deficiency in this element in early growth stages of the crop is difficult to overcome and the strong precipitation and adsorption of P in fertilizers with soil into non-plant-available forms typically mandates application at rates considerably in excess of predicted plant requirements. Also, lead will react with phosphate fertilizers to precipitate P into non-plant-available forms and over-application of the P fertilizers will likely be required to compensate. However, these reactions preclude the surface application method normally employed for split applications of a fertilizer. A split application will supply part of the needed fertilizer at planting and the rest a third or midway through the growing season. This technique is usually recommended for easily leached elements like N and K to optimize fertilizer use by the crop and to prevent leaching of unused fertilizer.

16. Install protective fencing around the area, if required, and establish work and decontamination zones.

17. Eradicate existing vegetation and remove trees as needed. Tree removal is especially critical not only to eliminate shading, but because roots may extend for considerable distances from the main trunk. If such roots extend into the remediation zone, they not only will use soil moisture at the expense of the crop, but they may also be affected by soil amendments and solubilized lead to the point where damage or death of the tree occurs.

18. To facilitate farming operations, visible obstructions, such as large rocks and metal scrap, should be removed from the area.

19. If necessary, excavate the soil, dry screen to remove debris, and wet sieve to remove particulate lead. Based on the soil texture and hydraulics, install a liner and leachate collection system and replace the soil.

20. Till the area with the appropriate equipment. For proper seed bed preparation, it is recommended that tillage be to a depth of at least a foot, if possible. Tillage should be done in at least two passes at right angles to each other. This may be done with a tractor-mounted, power takeoff-driven Rototiller.

21. Apply and incorporate fertilizer using the appropriate application equipment. This step may also be performed simultaneously with planting.

22. Install irrigation systems for the remediation area. These may be either overhead sprinkler, center pivot, or drip systems, depending on the crop and the logistics and physical layout of the remediation area. A drip delivery system, either surface or subterranean, may also serve as the soil amendment delivery system. However, the system should supply amendments at a delivery rate that will rapidly saturate the soil without causing runoff. Rapid saturation is required to maximize the amount of soil lead solubilized for plant uptake while minimizing potential damage to the plant by the soil amendments.

23. Apply necessary pre-emergent herbicides as recommended by extension service. The herbicides prevent weed establishment by killing the weed as it germinates in the soil. The herbicides are crop and site-specific.

24. Plant the crop with commercial tractor-mounted farming equipment. If a row crop such as corn is the first crop planted, a conventional seed drill may be used. If a broadcast-seeded crop is used as the first crop, a tractor-mounted hurricane seeder/spreader will be used. Plant seed at recommended agronomic rates to promote optimum stand establishment, growth, and biomass yields.

25. Tend the crops by cultivation to destroy weeds, or alternately, apply post-emergent herbicides recommended by extension service. These herbicides are specific for location and general class (broadleaf or grass) of weed. Apply recommended fungicides as needed during periods of excess rainfall when crops are susceptible to fungus infestation. Apply recommended insecticides specific for the insect pest, as needed.

26. Routinely inspect crops (especially early in the growing season) to evaluate any unusual coloration or other symptoms which might indicate a fertilizer or mineral deficiency and use a foliar application of chemicals to correct the deficiency before the crop growth is significantly stunted. Some common and most obvious symptoms to look for include purple stems and leaves, which may indicate P deficiency; the yellow leaves, which may indicate N deficiency; and the light-colored striping on leaves, which may indicate Fe or Zn deficiency. Other symptoms include: stunting, curled leaves, dead spots on leaves, or lacking other obvious visual signs, a general difference in appearance from the total plant population.

27. Commence pre-amendment sampling immediately before addition of soil amendments to solubilize lead. This will involve obtaining a limited number (12 per acre) of soil samples at 0- to 12-inch depth across the entire remediation area. This sampling will be done only once at the beginning of the project to establish background concentrations of COCs in soil before adding soil amendments. Thereafter, this sampling will not be necessary.

28. Add soil amendments. The application should saturate the soil quickly, without exceeding the infiltration rate of the soil, in order to reduce puddling and standing of solutions on the soil surface or surface flow of solutions across the plot area. Complete elimination of surface movement will be difficult if the site is on a slope, since uniform infiltration will not occur across the entire remediation area. This is caused by differences in soil texture. Areas of higher clay content will exhibit slower infiltration and may be conducive to surface flow. As a precaution, berms should be constructed around areas where reduced infiltration may occur, particularly on slopes, to prevent runoff of amendments outside of the plot boundaries. However, the rapid rate is required to minimize damage to the plants by the amendments. Ideally the contamination will be no more than one-foot deep, and thus the acetic acid and EDTA should be added to acidify the soil and solubilize lead to a depth of one foot.

29. Allow sufficient time for maximum lead uptake by the crop and subsequent plant senescence. These time periods will allow sampling and harvest before the plants become desiccated and brittle to the point where the tissue shatters with handling. For example, if corn and mustard are the remediation crops, this will be about four days for corn plants and two days for mustard plants. The time may vary with different plant species and the plants should be monitored accordingly.

30. After the appropriate senescence period, conduct post-amendment addition plant sampling in the same fashion as the pre-amendment sampling. This sampling will be done to confirm the effectiveness of the amendment application in stimulating adequate lead uptake by the plants. The amount of lead in the plant is the direct measure of the technology effectiveness. The amount of plant tissue may also be used to calculate crop yields if an area of known size is sampled and the area equated to the entire field. The plant sampling will be done after each crop. This will be used to evaluate results and make necessary adjustments to “fine tune” the technology for each specific area. Conduct soil sampling at the end of three years to estimate the amount of lead reduction that has occurred in the soil, keeping in mind that it may be difficult to differentiate changes due to the inherent variability of lead concentrations in the soil. This will also provide ongoing monitoring of treatment effectiveness. The time required for remediation is based on the initial lead concentration in the soil and the predicted and calculated amount of lead removed from the soil each year. At the end of the proposed remediation period, for instance five years, comprehensive soil sampling will again be performed to evaluate the overall effectiveness of the program and to determine if continuation of the remediation effort is warranted.

31. Harvest the crop with commercial harvesting equipment such as combines for larger areas of one acre or more. The harvested crop is spread in a suitable area, usually within the

remediation area itself, and allowed to dry for 7-10 days, depending on ambient temperature. This will reduce the total weight taken to a smelter or landfill.

32. Transport the dried plant material to a smelter or landfill. Obtain a dry weight for the entire crop (yield) either by weighing on scales at the destination or by obtaining subsamples (4-6 standard size paper grocery bags of material), weighing the samples, drying at 150°F for 48 hours, and then re-weighing to determine the amount of moisture lost.

33. Perform a post-crop evaluation after each crop to determine the effectiveness of the treatment regime at that particular site. This evaluation will include a determination on the quantity of biomass generated by each crop and comparing it with known quantities of biomass from like crops grown in that region. If there is a noticeable deviation in biomass generated, then a detailed evaluation must be undertaken to understand the cause of the problem. Areas to be concerned about are incipient nutrient deficiencies which may not manifest visible symptoms, yet which reduce yields; similar effects of incipient toxicities; obvious toxicities caused by other contaminants, such as Be or Tl; insect infestations, fungus infections; soil-borne pathogens, such as nematodes; under-fertilization or leaching of added nutrients before being fully utilized by the crop; or the crop not tolerant of conditions at the site. It may be possible to substitute higher yielding varieties or silage-type crops to increase biomass yield and to use crops which are more specific for the area.

34. The post-crop evaluation must also include an interpretation of the quantity of lead removed per crop. If the quantity of lead removed is below the planned quantity, then the determination should be made as to whether the cause is related to the crop or the soil system or to a previous amendment application. If a crop was planted in an area where no previous chelate application has been made, possible corrections to the plant system include: (1) investigate use of alternate plant varieties or alternate crops which have equal capacity for lead uptake, but have a longer growing season and are higher yielding, and (2) investigate use of shorter growing season crops which may produce less biomass, but have greater capacity for lead uptake and then plant multiple crops. If the problem is soil related, then possibly adjusting the amendment rate to solubilize more lead may increase uptake by the crop. Lead plant uptake may be increased by using a faster delivery rate of the chelate to maintain a saturated medium in the soil for passive diffusion of lead to the plant root and to maintain the lead in the solution phase of the soil. If amendments were previously applied, possible remedies include deep-tilling soil to the depth of the liner or underlying intact soil strata to bring any lead that may have moved downward due to a previous chelate application back closer to the surface. This will allow more extensive root contact with soil lead.

35. Perform geostatistical analyses on soil sample data to re-map the area for lead concentrations and to determine the reduction in soil lead. This data may be used in conjunction with plant lead data to form a more complete picture of removal rates.