Contaminated Soil Excavations, Planning and Managing to Minimize Cost

Training Course
for
Engineers, Managers, and
Environmental Contractors

by

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Course Content

1. Introduction

Environmental cleanup operations commonly involve excavation and removal of contaminated soil resulting from historical practices at industrial facilities and military bases. A Remedial Investigation/Feasibility Study (RI/FS), or other equivalent environmental cleanup study, is conducted which identifies the "nature and extent" of contamination, and selects or proposes alternatives for cleanup. Under the federal Superfund regulations, a Record of Decision (ROD) is produced that selects the cleanup method to be used. Whether under federal or state regulations, a manager is many times required to contract or otherwise oversee environmental cleanup operations that include excavation and removal of contaminated soil. This course is designed to provide the basic approach for conducting these operations in a cost-effective manner and avoid common pitfalls typical with these operations.

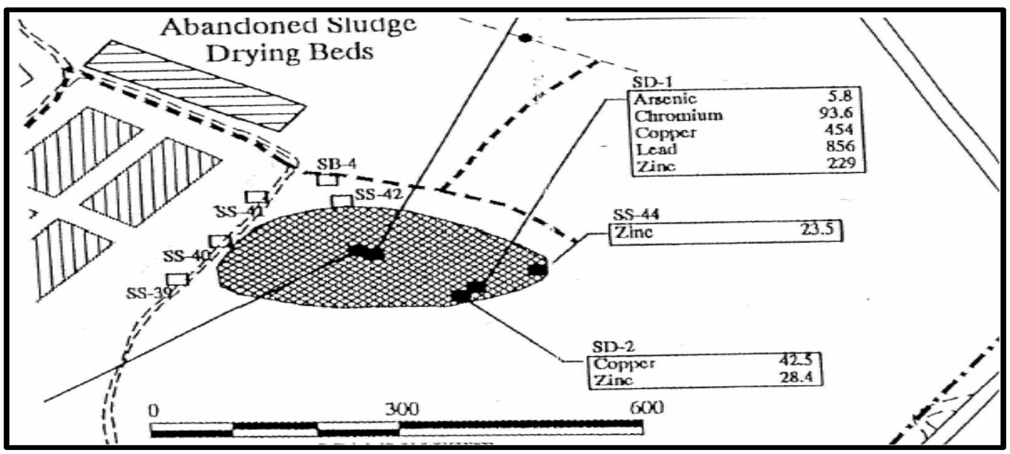
Excavation is not a sophisticated technology. There are lots of experienced excavation contractors available. The RI/FS is done and the ROD indicates what needs to be done. The general approach at this point is oftentimes to simply call in an excavation contractor to start digging. The excavation work can start in the area of contaminated soil. After a period of excavation, the bottom and sidewalls of the excavation are sampled to determine if the site is clean. If not clean, digging continues. This sounds like a reasonable approach and is many times employed.

Unfortunately, this approach can lead to a quagmire of digging, sampling, digging, and sampling. The excavation operations dig a few feet and then await results from the sample crew. The sample exceeds criteria, and the excavation operations dig a few more feet, and then wait around for the sample crew to sample and generate data again. In one case study, a simple removal action started for the removal of two cubic yards of petroleum-contaminated soil. One year and three contractors later, the excavation work had removed approximately 400 cubic yards of soil, funding had been depleted, and the job was not completed. Later, under new management, proper delineation was conducted, an additional 200 cubic yards was removed, and the site closed out successfully.

The problem of "ballooning" is a not uncommon in soil excavation operations, and this causes difficulties in areas of scheduling, funding, contracting, and general operations. An inefficient approach to the excavation, such as digging and sampling later to see if you got it all, can also result in an unknown amount of clean soil being excavated along with the contaminated soil. To avoid these problems, one needs to adequately delineate the site prior to excavation. This involves extending a grid over the site and conducting pre-excavation sampling. The data is then used to develop a preliminary and/or detailed excavation plan with adequately defined boundaries. This may seem reasonable if not obvious; however, in practice, this is typically not done (or not done adequately). One should be familiar with the reasons why, explained below.

Generally, at the point in time when a facility manager is looking into having excavation and removal operations performed, a number of studies have been completed at a facility and the manager is probably suffering from "sticker shock" because the cost of environmental studies tend to be more then most people think reasonable. In fact, a typical facility manager may have already paid for a Preliminary Assessment, a Site Screening Investigation, a Remedial Investigation, a Risk Assessment, a Feasibility Study, and a Record of Decision. At this point management probably believes the site simply needs an excavation contractor to complete the work. The last thing management expects to hear is a recommendation to extend a grid over the site and conduct pre-excavation sampling. It is not uncommon for meetings to become tense, and comments like "I am sick and tired of studying the problem. I want someone to do something for a change!" to be heard. If regulators and others are present, they will, of course, agree. Contractors generally want to do what the management wants them to do. Thus, the project begins without proper planning.

Unfortunately, the RI/FS or equivalent document almost never provides adequate information to commence excavation operations in an efficient manner **(Figure 1).**



Above: Typical remedial excavation as shown in ROD (solid squares exceed cleanup goals, hollow squares meet cleanup goals)

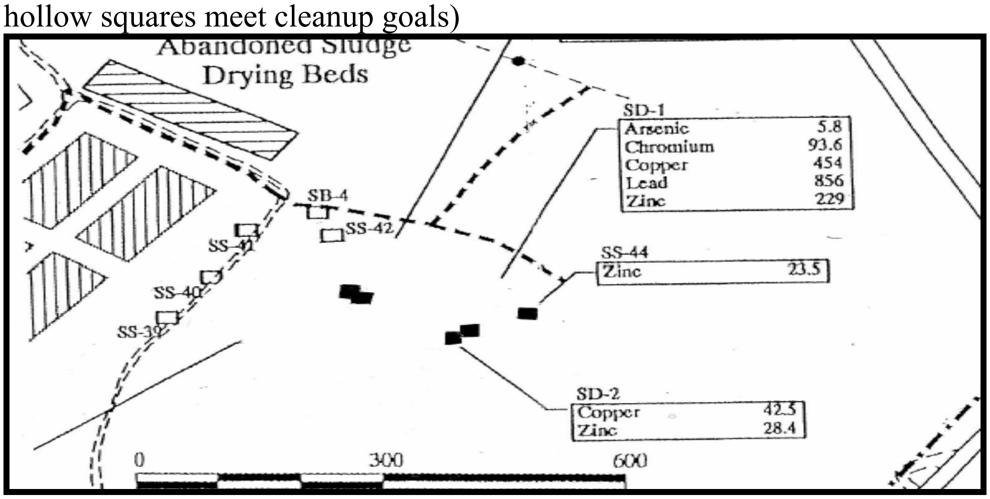


Figure 1: The first figure is typical of information provided in the ROD for site excavating activities. The second figure is more representative of site conditions. Except for the area to the northwest, there are no data to indicate excavation boundaries.

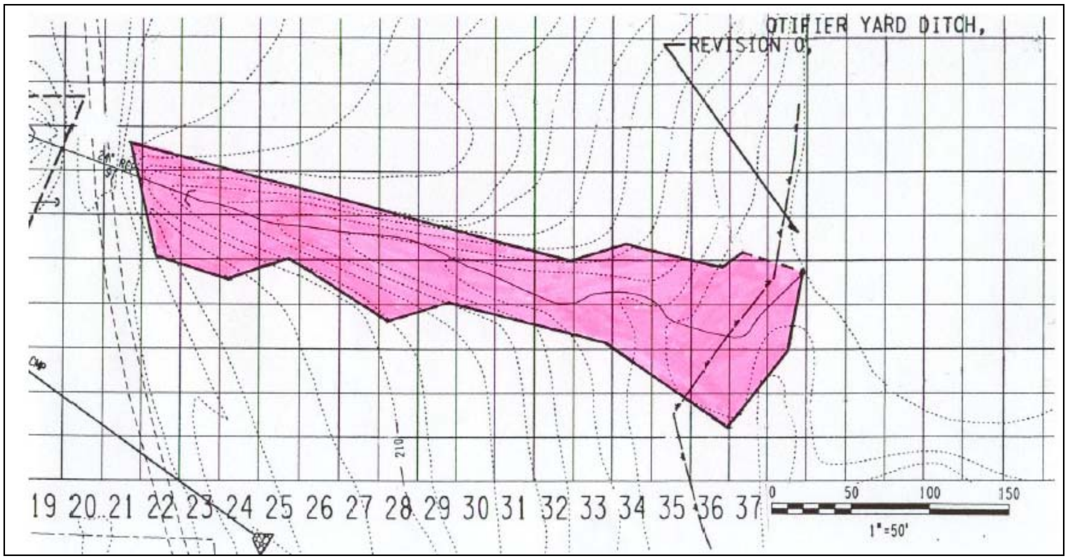
During a typical remedial investigation (RI) leading to excavation, a study is conducted that tends to look for a broad range of contaminants over a relatively large area, and the study tends to locate one or more smaller areas of contamination in general. The samples tend to be expensive because of the broad range of analytes and the quality control (QC) requirements needed for risk analysis. The RI data is then analyzed for risk to human health and the environment, and the broad list of potential contaminants of concern is eventually narrowed down to one or more contaminants that need to be cleaned up. At this point, a feasibility study (FS) or equivalent study is completed to evaluate cleanup alternatives. During this process, assumptions are made with regard to the boundaries and volume of contaminated soil to be excavated. Actual boundaries and volumes, however, will vary, sometimes quite considerably, from the estimates made in the FS.

There is no substitute for pre-excavation delineation sampling to verify true boundaries of the site. Grid-based delineation sampling should be conducted to provide a valid estimate of soil volume before excavation begins. If the area of excavation (and cost) is going to balloon, this will become evident at this time **(Figure 2)**, and appropriate planning can be performed for the project.

Once the site is reasonably defined with boundaries identified, a management review of the cleanup strategy should be conducted. Do not assume that you are strictly locked into the details of a pre-selected cleanup alternative. Details of the cleanup alternative can be changed with regulatory approval. The management review may result in a re-evaluation of cleanup standards, reworking of the risk assessment, a look at modeling, compliance averaging techniques, and/or a change in treatment or disposal method. Once the cleanup criteria and disposal method are set, additional sampling to refine the excavation plan and reduce excavation size is recommended. The degree of refinement of the outer boundary is determined by comparing cost of additional sampling to savings from reduced excavation.

Experience has shown that environmental excavations/removals are better managed using a systematic approach that includes the following elements: (1) Extend a grid over the contaminated area and perform delineation sampling to determine the true boundaries and develop a preliminary excavation plan, (2) Perform a management review of cleanup strategy based on increased knowledge of the site and currently available options, and (3) Refine the excavation plan to optimize the removal action and reduce excavation requirements.

This course will provide guidance for conducting or managing excavation operations for environmental cleanup of contaminated soil from historical practices. The overall approach and methods, techniques, and examples for optimizing these operations are provided in this course.



Top: Original excavation shown in pink. Bottom: Final boundaries include area in yellow

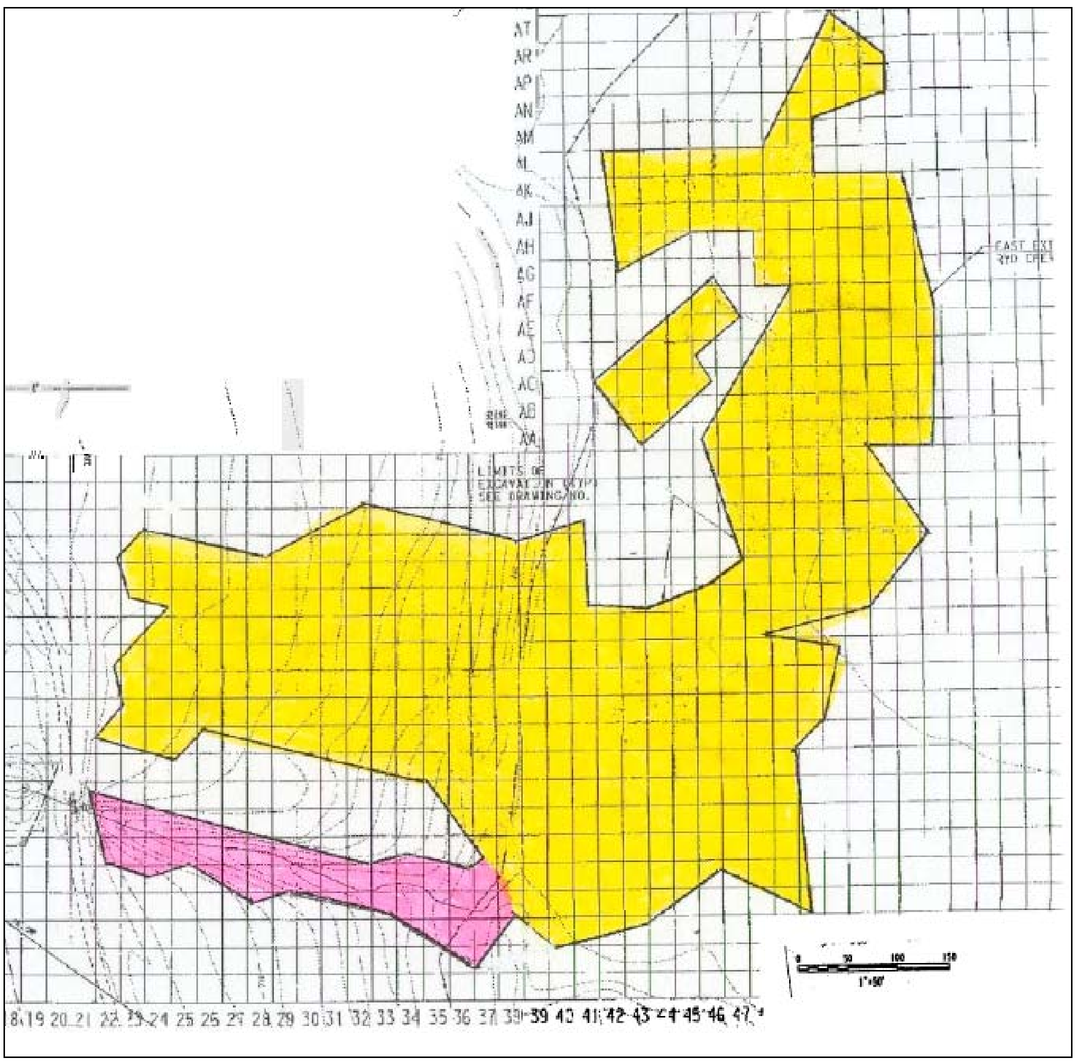


Figure 2: Top shows excavation of a PCB site, believed to be essentially complete except for a small amount of additional excavation as indicated by sidewall sampling at the northeast corner. Bottom shows final boundaries to be much larger then imagined.

2. Developing the Preliminary Excavation Plan

One of the most important elements to be in place prior to start of the excavation is an excavation plan with properly defined boundaries. To develop a preliminary excavation plan, data need to be gathered on the site to verify the boundaries of the impacted soil. A grid should be extended over the site and the site sampled in a systematic fashion. One of the most important goals of the grid-sampling plan is to define the outer boundaries of the impacted soil.

2.1 Pre-excavation Grid Sampling

Several key elements to consider are grid size, numbering system, and analytical method. It is common for several rounds of sampling to be necessary to adequately delineate the outer boundary of contamination. Therefore, the sampling approach should be flexible and anticipate several rounds of sampling.

2.1.1 Grid Setup

A grid is necessary to provide a means of distributing the samples in an efficient manner, and to provide a means to number, track, and easily locate sample points on a map and on the ground. There are several formulas and methods available for calculating grid size based on probability to detect "hot spots" of a given size or shape. However, for delineation sampling, the area of contamination is already identified and the goal here is to find and verify the outer boundary, and refine the area of excavation as necessary. In this instance, grid size should be based on best professional judgment (BPJ) considering previously collected data, the size and shape of the site, and topographic features. The grid should not be set so small such that an excessive number of samples are collected in the interior of the area, because the initial goal should be to identify the outer boundaries of contamination.

2.1.2 Numbering System

An alpha-numeric numbering system, such as commonly found on road maps, is recommended as a basis for setting up the sampling grid. Without such a tracking system, as sample numbers increase, the effort to track and locate data points on a map and in the field tends to grow exponentially. An alpha-numeric numbering system will allow a relatively easy means of connecting analytical data to locations on maps and on the ground. The numbering system should allow or anticipate expansion of the grid, which is a common occurrence.

2.1.3 Analytical Methods

Details on various analytical methods should be provided in a project-wide sampling and analysis plan (SAP), and is beyond the scope of this course. A good general approach for developing a SAP for support of excavation operations is provided in **Exhibit A**.

For pre-excavation grid sampling, the analytical methods used should be adequate to identify the presence of the contamination at or near the cleanup level. The general goal should be to select cost-effective methods that allow larger numbers of sample to be collected and processed. Methods preferred for this application include field analytical methods such as immunoassay technology, x-ray florescence (XRF) and field GC methodologies. However, off-site laboratory data for metals and some organic analytes may be competitive and also have the advantage of being acceptable for site closure purposes. Off-site sample data that are validated under stringent regulatory validation protocols are generally costly, time consuming, and unnecessary at this point, and are typically reserved for verification of cleanup.

Exhibit A – Developing a Sample Plan to Support Remedial Excavations

The sampling plan should include a three-phased sampling approach to support site remediation. The plan should include Phase I, "Delineation Sampling," which describes extending a grid over the sites and sampling to delineate excavation boundaries; Phase II, "Excavation Sampling," which involves sampling during and/or after excavation to guide excavation and to indicate when contaminated soils have been removed, and Phase III, "Confirmation Sampling," to verify cleanup goals have been attained.

Prior to Phase I sampling, historical and/or any previously collected data should be evaluated and, previous sampling locations and features located to define the known areas of contamination, to the extent practical, for the sites to be excavated. Based on the existing data, a Phase I sample plan should be developed that includes extending a grid pattern over the area and collecting samples to delineate the boundaries of the contaminated area. Samples should be screened and/or analyzed for one or more of the contaminants of concern (COCs) applicable to the excavation of the site. Analytes that are not applicable to the excavation should not be analyzed or reported. After the outer boundaries are initially determined, the boundaries will be refined to reduce over-excavation of clean soils.

Phase II, "Excavation Sampling," involves sampling during and/or after excavation, as needed, to aid and guide excavation activities. This includes focusing on any known or suspected "hot spots" and/or areas of visible contamination during excavation. If applicable, Phase II sample data may be used to indicate when site concentrations meet the cleanup goals for the site. Phase II samples may be used to screen Phase III samples/sample locations prior to off-site analyses of Phase III samples.

Phase III, "Confirmation Sampling" or "Verification Sampling" involves sampling to verify that site concentrations meet cleanup goals for the site. These samples are normally required to be analyzed by an off-site laboratory and meet laboratory validation standards. These samples should be of the appropriate data quality level to meet regulatory concerns.

Analysis and data reporting should be limited only to those contaminates of concern (COCs) that drive the excavation. During the RI phase, low-level detections of various non-COC contaminants are typically found, and these are generally evaluated and dismissed as a concern. During the cleanup phase, reporting of extraneous detections often results in regulators requesting additional excavation that is not required.

Many times an otherwise good field analytical method is automatically rejected if site cleanup levels are below the method detection limit. This makes sense in the case of confirmation sampling, but not necessarily for field analytical purposes. Field analytical methods should be evaluated for their ability to adequately locate boundary areas and otherwise provide useful site information, such as locating of "hot spots."

> Staff chemists and QC personnel had disqualified the use of an immunoassay field method for a field operation because it had a detection limit of 1 ppm DDT, which was above the site cleanup goal of 0.7 ppm. The test kits were used in spite of the objections, however, and performed flawlessly. Contaminants at the site ranged from well over 10,000 ppm to zero over distances of 25 to 30 feet, and finding the boundary to within 0.3 ppm with a field method was actually quite remarkable.

2.1.4 Special Precautions when Sampling for Trace Contaminant Analysis

When the cleanup goals for the site are in the parts per million, parts per billion, and/or parts per trillion range, extreme care should be taken to prevent cross-contamination of these samples. Cross-contamination can result in data that erroneously indicate areas of contaminated soil for excavation, when in fact the area may be clean or below cleanup goals for the site. The following precautions should be taken when trace contamination is of concern:

- Sampling equipment and supplies must be staged on plastic sheeting or equivalent to prevent contact with potentially contaminated surfaces. A new pair of disposable chemical-resistant gloves must be donned immediately prior to sampling
- All sampling equipment must be properly decontaminated prior to sampling, and QC samples must be collected as specified in the QC plan
- Sample jars containing high concentrations of contaminants should be capped tightly, wiped clean, sealed in plastic bags, and stored separately from samples believed to be of low concentrations
- If very high concentrations are present at a site, sample collection activities should generally proceed progressively from the areas of lower contamination toward the areas of higher contamination, if possible

Soil sampling equipment used for sampling for trace contaminants should be constructed of stainless steel when possible. Pans used for mixing should be made of stainless steel or glass. In no case should painted, chromium, cadmium, or galvanized plated or coated equipment be used for soil sampling operations. All paint, foreign matter, and excess rust must be removed from down-hole soil sampling equipment and tools by sandblasting or other means before such equipment can be used for drilling and collecting soil samples.

Sampling equipment must be properly decontaminated and protected from potential sources of trace contamination during storage and handling.

All down-hole equipment and materials should be protected from sources of contamination during storage and handling prior to placing in hole. When sampling from a borehole, precautions should be taken to avoid sampling the cuttings or cavings that fall to the bottom of the hole, so that possible contaminated surface soil does not contaminate a subsurface sample. After retrieving the sample device, the upper portion of the sample should be trimmed to remove any cuttings or cavings that are not native to the interval being sampled.

Subsurface samples should be collected in a manner that prevents cross-contamination from surface material. Smearing from 2 inches of gray surface material (right) is seen down the length of a 2-ft split spoon sample.

With the exception of samples for volatile organic contaminants (VOCs), it is extremely important that the soil sample be mixed and homogenized as thoroughly as possible. The laboratory will typically take only a spoonful of soil from the sample jar, so thorough mixing is essential to ensure that the laboratory aliquot is representative of the sampled material.

Samples for VOCs, however, must be collected in a manner that minimizes loss of VOCs, and are never homogenized in the field. VOC samples may be collected directly into the sample container or must be containerized immediately upon retrieval in an appropriate VOC container, and preserved as appropriate.

VOC samples should be containerized/preserved immediately on retrieval, or collected directly into the container.

One should keep in mind that a mislabeled sample container can cost thousands of dollars in remediation costs; therefore, care should be taken to assure samples are not mislabeled. Multiple samples are generally processed at the time of collection. Temporarily unmarked samples (i.e., push tubes, split spoons, mixing bowls, unlabeled jars, etc.) should never be placed in the vicinity of other similar unmarked samples, as this may lead to identification errors by a busy sample crew.

2.2 Preliminary Excavation Plan

2.2.1 Approach to Defining Boundary

The approach for developing the preliminary excavation plan and later refining the excavating plan is based largely on the method for defining the boundary of excavation. There are different methods for developing excavation plans and setting the boundary of excavation based on sample data. One approach is to draw an excavate boundary halfway between clean and contaminated locations, and then excavate to that line (**Figure 3**).

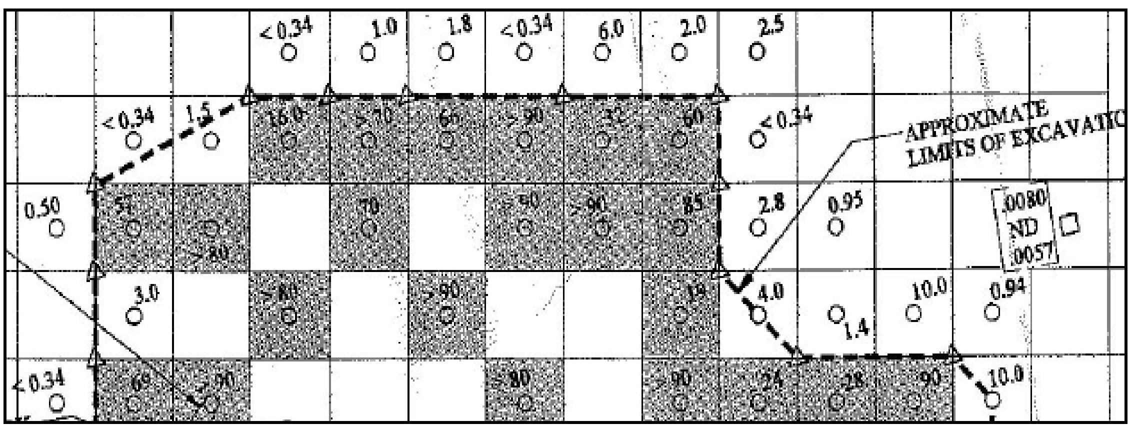


Figure 3: Example of excavation plan with estimated boundary

Another method is to use computer-modeling methodology, such a kriging[1] or triangulation, to estimate the boundary of contamination based on nearby sample locations. Excavation is performed to this line, and the edge of excavation is then sampled to determine if all the contaminated soil was removed. If contaminants remain, then additional excavation is performed.

[1] Kriging is the estimation procedure used in geostatistics. It uses known values at known locations to estimate unknown values at a given location, based on the estimate changes between known values with distance. It was named after D. G. Krige from South Africa.

The method followed here is simple and straightforward: to use actual data points for the boundary of excavation, with pre-excavation sampling to refine the boundary as necessary prior to excavation. This has the advantage of assuring that the boundaries between clean and contaminated areas are more accurately defined. This tends to minimize the over-excavation of clean soil and the under-excavation of contaminated soil, which occurs when the boundary is estimated and excavation is initiated. Using actual sample locations also tends to minimize the need for additional rounds of excavation.

Another reason to use clean sample data points to define the boundary is to minimize worker exposure to site contaminants and minimize the potential spread of site contaminants. In the field, excavation boundaries are staked out, and silt fences are commonly installed or otherwise the site is roped off in some manner. It is then typical for excavation crews to set up equipment outside the fence and proceed to excavate contaminated soil inside the fence. If the boundary is estimated under kriging or other means, the silt fence probably does not coincide with the actual boundary of contaminated soil.

> At one site, crews set up and operated equipment from an assumed clean zone outside the fenced off area marked for excavation. Later, after several rounds of excavation and sampling, which extended into the clean zone, it became apparent that the assumed clean zone was more contaminated than the original excavation, with levels of PCB contamination exceeding 300 ppb.

2.2.2 Starting the Preliminary Excavation Plan

The preliminary excavation plan is started by using data collected from the first round of pre-excavation sampling, and other previously existing data that are available and can be located adequately. The preliminary excavation plan is developed by connecting "clean" sample points along the perimeter of the site, as shown in **Figure 4.** Solid lines should be used to delineate a boundary defined by sample locations that are below cleanup criteria. For areas that do not have a clean outer boundary defined, place proposed sample locations on the grid map, and use dashed lines to represent the preliminary or "yet to be defined" boundary.

The objective of preceding rounds of sampling is to further develop the preliminary excavation plan. The grid is extended and additional samples are collected as necessary to find the outer boundary. If the boundary is not located after several rounds of sampling, the step-out distance may need to be increased. Both the depth and outer boundary should, at a minimum, be defined prior to start of excavation. After the outer boundary is fully defined, the preliminary excavation plan should be further refined, which will be explained later in Section 4.

The estimate of soil volume and disposal costs for the project should be updated as the preliminary excavation plan develops. If the grid continues to expand and the site is doubling or tripling in size, the site is "ballooning." This is a case where the estimated excavation volume and cleanup cost seems to grow exponentially as more data are collected. A management review of the cleanup remedy should be conducted at this point (Section 3).

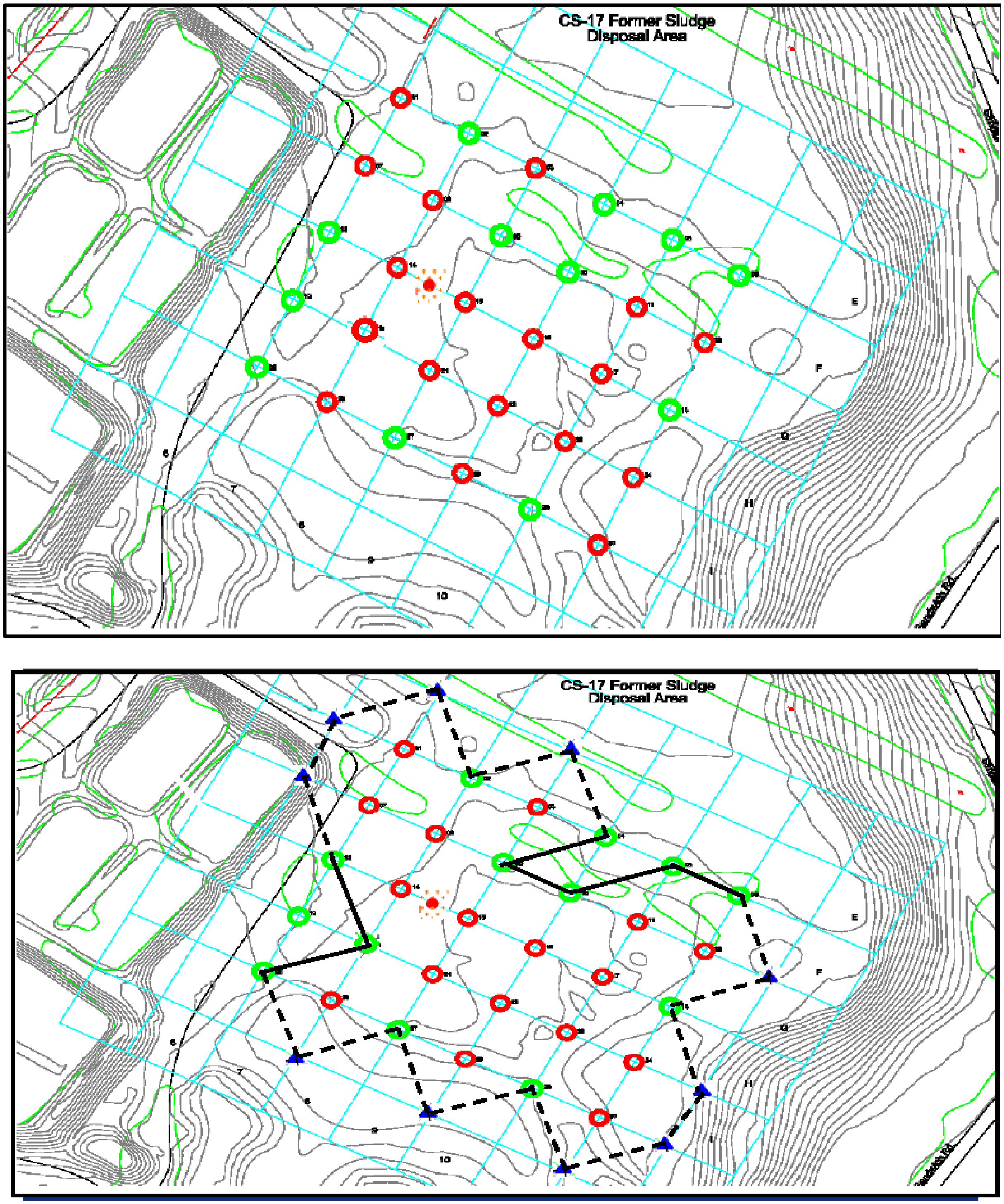


FIGURE 4: Top – Grid Sampling Data
Bottom –Start of Preliminary Excavation Plan Development

LEGION: (Solid Line) = Known Boundary; (Dashed Line) = "Yet To Be Defined" Boundary
= Exceedance; = Clean; = Proposed Sample Location;

2.2.3 Depth Requirements for Preliminary Excavation Plan

2.2.3.1 Surface Soil Contamination

Prior to excavation, the depth of contamination should always be confirmed. Contaminants that have spread due to historical facility practices are quite often contaminants that are relatively non-soluble in nature, such as PCBs, pesticides, and inorganics. Many times these are found to have spread over the surface of an area over time, or in ditches and drainages, and are not present to any extent at below the surface. Typical excavations in these situations are generally limited to the first one or two feet. Exceptions include areas that have been backfilled, regraded, or where these contaminants have gotten in drainage features that lead underground. A basement foundation set on crushed stone, for example, resulted in PCB contamination 15 feet below grade, but this is not typical. Recognizing that many exceptions apply, environmental remedial excavation/removals from historical facility practices tend to be for contaminants in surface soil.

Sampling strategy for sites that have contaminants that tend to spread over the surface may involve initially collecting samples at two depth intervals (e.g., 0-1 foot and 1-2 feet), to verify contamination is limited to surface soils. Once confidence has been gained that contaminants are limited to the upper one foot or so, there is generally no need to continue to collect below this interval. Another approach is to define the surface area first, and then go back and determine depth at several locations.

Although this course advocates determining depth of contamination prior to excavation, there are exceptions. At one site, rocks and boulders made subsurface sampling exceedingly difficult. In this case the best approach was to excavate and sample the bottom of excavation.

2.2.3.2 Subsurface Soil Contamination

Another example of a type of contaminant release are releases common to petroleum fuel and solvent spills, originating from underground storage tanks, pipelines, or other spills that have occurred over time. These spills tend to travel downward rather than outward, especially in sandy conditions. These tend to be limited in area, but the volume of soil can be substantial because of depth. Excavating a few feet of solvent or fuel-contaminated soil can be cost effective, but as depth increases, excavations become problematic and may be unnecessary. In sandy soils, sloping requirements may greatly increase the size of the excavation with depth, or shoring may be needed. For petroleum fuel or solvent related contaminants that extend down to 15 to 20 feet or more, and depending on the volume present, there are better remedial technologies available, such as Soil Vapor Extraction (SVE) or bio-venting, which are typically suitable for these situations.

Firefighter training

In summary, for fuel- or solvent-related contaminants, the determination of depth is critical. If the spill exceeds a cost-effective depth for excavating, and an in situ technology like SVE is going to be used, there is generally no point in conducting any near-surface excavation. This is because the SVE technology typically will economically treat the soil up to the surface. In this case, you don't want to start excavating and later learn the depth is such that you should have used SVE technology.

An enthusiastic contractor wanted to quickly excavate a jet fuel spill at a crash site in desert terrain, and was prepared to excavate the five or so feet of soil in one day. After excavating to five feet, they saw more excavation was needed. At 10 feet they were sure that almost had it all. At 20 feet they figured they might as well keep going. They finished at 30 feet and with a crater 60 feet in diameter.

Soil Vapor Extraction System

3. Management Review of Cleanup Strategy

Once the preliminary excavation plan has been developed, a review of cleanup strategy should be performed. For small sites were the soil volume is in line with expectations, this may be just a check that things are going as planned and assumptions are valid. The selected disposal option, however, should always be double-checked to ensure that it is the most appropriate and/or economical for the volume of soil, contaminants, and concentrations found at the site.

For larger sites, or sites that have ballooned in volume to be larger then expected, this step is more critical. Strategies to deal with large or larger than expected sites include the following:

- Re-evaluate selected cleanup criteria
- Perform or revise risk assessment for site
- Evaluate and/or perform leach modeling, if applicable
- Evaluate applicability of compliance averaging, if applicable
- Re-evaluate treatment and/or disposal method

3.1 Re-evaluate Selected Cleanup Criteria

It is not uncommon for excavation/removal cleanup operations to be based on published screening level criteria, especially for small sites. This avoids the cost of performing more involved risk assessments, which may not be justified for a small site. However, if these values are at or near background levels, the site boundary may grow far beyond anticipated. Also, some ecological risk based screening values are actually below background levels in many parts of the country. Cleanup values set at or below background levels can inadvertently lead to ever-expanding site boundaries.

A problem to be aware of when using background values as the cleanup criteria is explained here. Let us suppose a site cleanup criterion is a background value, which is based on the upper 90th percentile of values found across a given region. Let us use zinc in this example. In this case one in 10 samples may, on average, detect a marginal exceedance under normal background conditions. Now, let us suppose five or more of these background criteria are selected for the site; for example, zinc, copper, lead, chromium, arsenic, mercury, and manganese. The cleanup goals may now be inadvertently set such that 50% or more of the samples may exceed cleanup levels under background conditions. In this instance the excavation boundary would extend indefinitely, because one would be delineating background conditions, and the cleanup criteria would need to be re-evaluated or renegotiated.

3.2 Revise Risk Assessment

There are different methods and forms of risk assessments that vary from simple to complex. Most environmental cleanup sites have had a risk assessment of some type performed on the site, and this forms the basis for the cleanup criteria. Risk assessments vary in quality and complexity depending on the level of effort and amount of data that are available at the time. It is not uncommon for risk assessments to perform with a minimum of soil data, and based on the highest detected contaminant level. The cleanup criteria are often based on screening values and/or published values designed to be protective of human and ecological receptors.

Revised risk assessment resulted in no excavation of wetland

Risk assessments that are more then a few years old may no longer be current with regard to the latest regulatory guidance and ecological risk values. Also, by the time the preliminary excavation plan is developed, many more data will likely be available on the site than were available when the risk assessment was conducted. Except for small sites, it is generally worth taking a second look at site risk and cleanup criteria to verify if they are appropriate for the site. A person trained in risk assessment work should be able to evaluate current site information and site cleanup criteria, and then provide a recommendation on whether a revised risk assessment should be conducted to develop new cleanup levels. Revised risk assessments have resulted in no further action (NFA) or reduced excavation actions at many sites. **Figure 5** shows the dramatic effect on excavation plans at one site as a result of revised cleanup criteria (referred to as remedial action levels, or RALs).

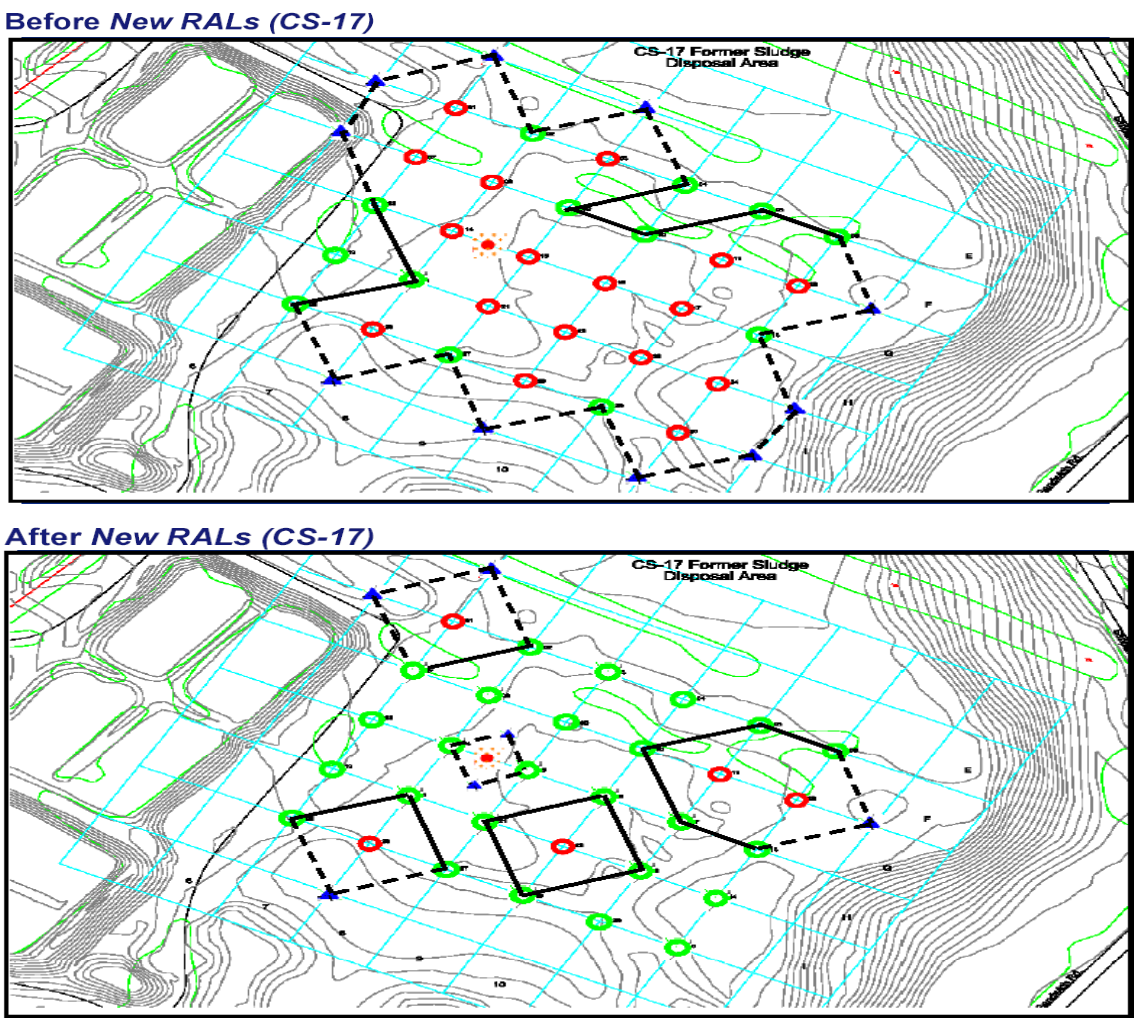


Figure 5: Before and after new cleanup criteria are calculated

3.3 Leach Modeling

In some cases the cleanup criteria are for organic compounds and are based on published values designed to assure the contaminants do not pose a threat to groundwater. These cleanup criteria are based on the leaching potential of the contaminant, and a number of assumptions about site conditions are used to develop them. These criteria are generally conservative in nature and assume worst-case scenarios so they can be applied to a variety of sites across a state or region. In this situation one may wish to develop more site-specific cleanup values.

Computer software acceptable to regulatory agencies is readily available and performs calculations to simulate or model leaching potential for various compounds under various conditions. Leach modeling can be performed using site-specific data to develop more realistic scenarios for a given site. The modeling may show that the excavation can be reduced to a smaller "hot spot" or that excavation can be eliminated altogether for a site with borderline exceedances (**Figure 6).** One may also consider collecting groundwater samples beneath the site, if this has not already been done, to see if leaching is actually occurring.

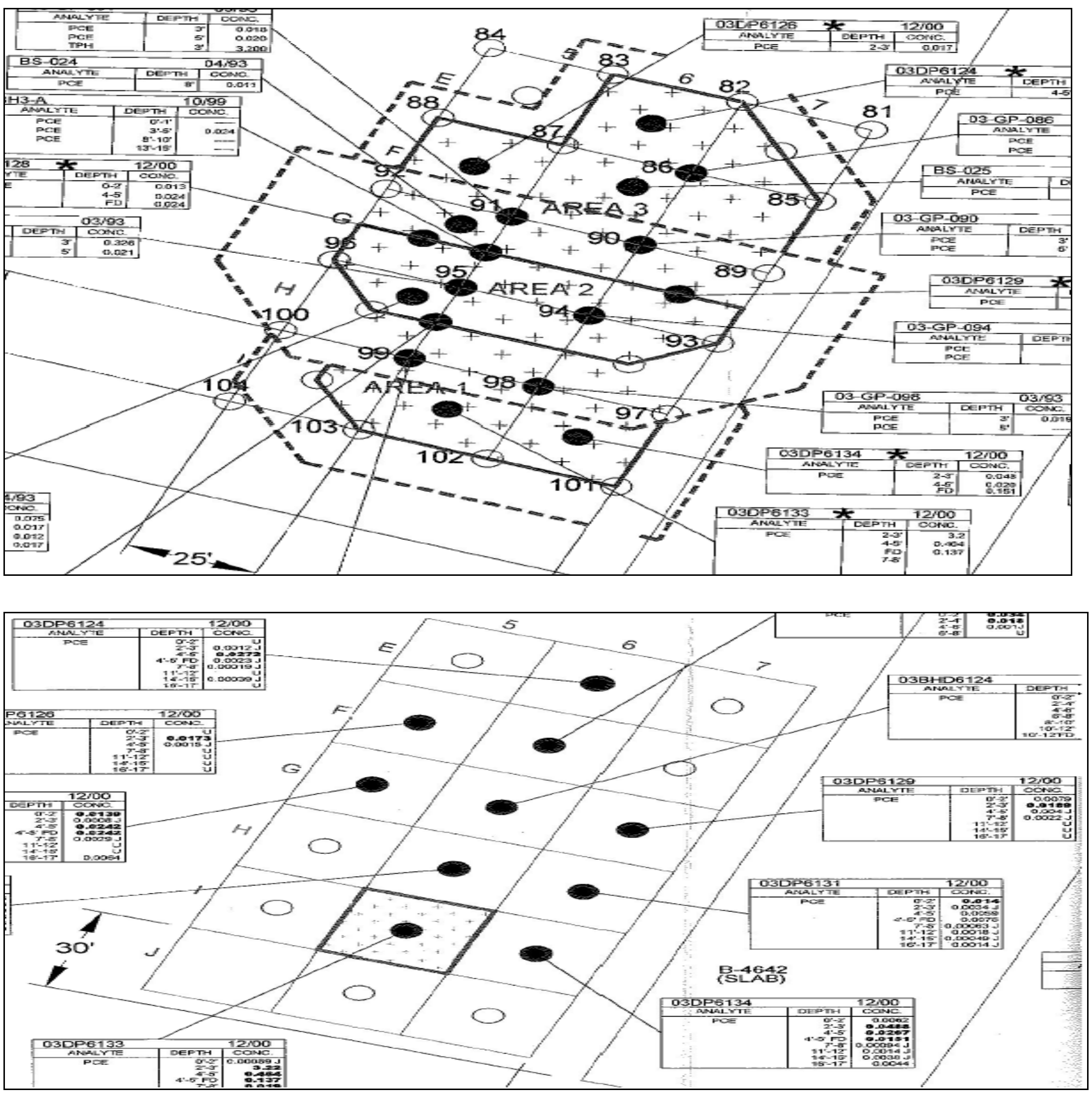


FIGURE 6 Top - Original preliminary excavation plan, to excavate each exceedance. **Bottom -** Revised excavation plan. Leach modeling data showed that, after excavating the one grid shown (I-6), the residual contaminants would pose no threat to groundwater.

3.4 Laboratory Contaminants

Incredibly, remedial activities for contaminated soil have been planned and conducted at sites where the contamination was never present (**Figure 7).** The contaminants were not at the site, but were present at the analytical laboratory hundreds of miles away. Laboratory contaminants, at trace levels, are commonly reported in laboratory data for soil and groundwater samples.

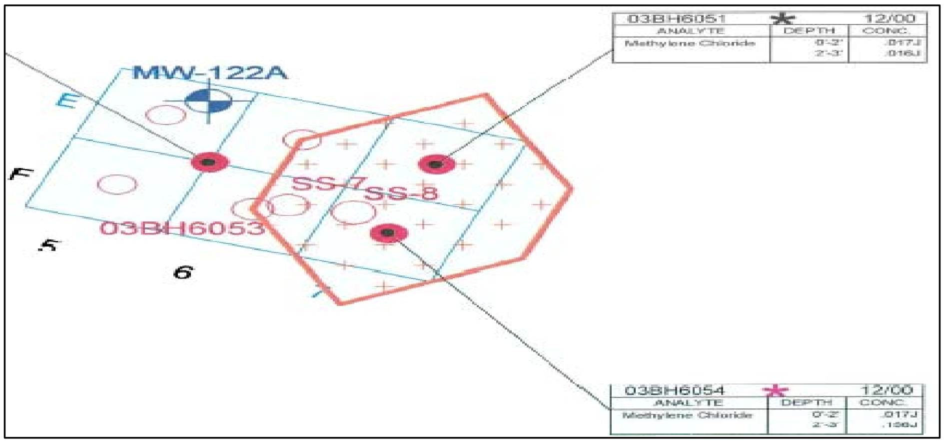
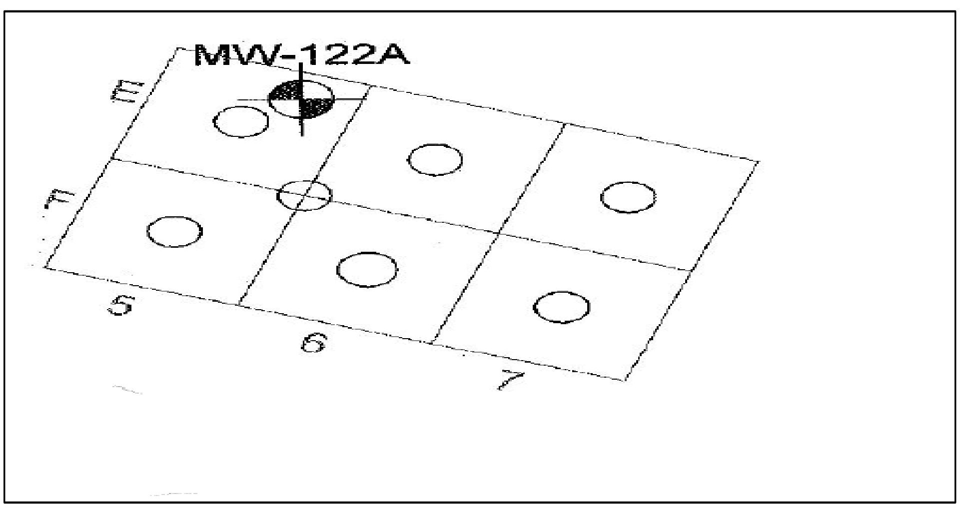


Figure 7: Top – Preliminary excavation plan for methylene chloride contaminated soil
Bottom – Same locations were re-sampled and sent to a different laboratory, resulting in no detections of contaminants and no excavation



These contaminants include methylene chloride, acetone, chloroform, phthalates, and hexanone. For soil, it is common for data to show these detections for soil samples, but not in the trip blank, leading one to conclude that it is indeed in the soil. Trip blanks, however, are typically aqueous, and are handled differently in the lab then soil samples. For soil samples, the lab will add their laboratory water to the sample prior to analysis, and many times this is the source of the trace contaminant detections. Also, laboratory contaminants tend to show up sporadically, so lab contaminants not present in a trip blank does not mean they are not present in another sample.

Sample data showing trace concentrations of volatile compounds that are also common laboratory contaminants should be viewed with skepticism when considering remediation. The locations should be re-sampled and sent to a different laboratory with an explanation of the suspected problem. Trip blanks and/or blind blanks using the soil matrix should be shipped with the samples.

3.5 Re-evaluate the Cleanup Option

In many cases, the cleanup and disposal option selected in the feasibility study is implemented without an appropriate re-evaluation or "reality check" prior to execution. Treatment and/or disposal options selected during the feasibility study are generally derived from a number of assumptions with regard to the cost, volume, transportation, contaminant concentration, etc. These estimates vary in quality. Some estimates, for example, are derived from tables and graphs, and actual quotes from subcontractors or disposal facilities may be quite different.

After the preliminary excavation plan is developed, a more accurate estimate of soil volume and soil classification should be made, and a re-evaluation of currently available treatment and/or disposal options should be conducted. It is not uncommon to find better and/or more economical treatment and/or disposal options that are available. One example is a site where pre-excavation sampling of apparent shallow soil contamination found that the contaminant actually extended to a depth of 25 feet. In this case it was found that SVE technology was a better cleanup alternative. More common, however, is a better selection of off-site disposal option. Waste disposal brokers are available to submit estimates for off-site disposal costs.

4. Refine and Optimize the Excavation Plan

After the preliminary excavation plan and management review of cleanup strategy are competed, the next step is to refine and optimize the excavation plan. At this point the preliminary excavation plan should have flushed out potential problems with the site with respect to size, and the selected cleanup alternative is set. Also, costs for excavation and disposal should be known. The excavation plan should now be evaluated for the degree of refinement that is appropriate. The plan also should be evaluated for approaches that may be used to limit excavation and still meet cleanup goals. In this section, we will look at methods for optimizing excavation plans.

4.1 Refine Boundaries

The preliminary excavation plan should be evaluated for further refinement. Refinement refers to collecting additional samples to refine boundary areas and eliminate over-excavation. The degree of refinement is determined by comparing the cost of additional sampling versus the costs of excavation and disposal for a given area and depth. Although this evaluation is fairly easy to do, in practice this is typically not done.

> A site superintendent prepared to excavate a pesticide site in southern Florida. The site was about an acre in area, and the sample crew had completed delineation of the outer boundary of the site on a 25-ft grid scale. The sample team leader recommended additional sampling, but the superintendent decided to send the sample crew home. This is done to minimize sampling costs.
>
> Meanwhile, in northern Maine, another site superintendent oversaw excavation at ten sites. After initial excavation, he had the sample crew collect bottom and sidewall samples. At locations where an exceedance was detected, he excavated one truckload of dirt and then re-sampled. This was done to minimize the excavation/disposal costs.
>
> The superintendent at the first site did not realize it, but for each of about 30 grids, he was going to remove $9,000 of dirt rather than collect a $50 sample, and his plan would have cost the client $200,000 over necessary costs at this one site alone. At the second site, for various grid locations, the superintendent had a $2,000 sample collected in an attempt to avoid removing $200 of dirt. Each time the sample detected an exceedance, he had the $200 worth of dirt removed, and then collected another $2,000 sample.

The decision on how many samples to collect and why in order to optimize excavation is typically not understood by earth moving contractors, environmental consultants, or the client. Many companies can move lots of dirt cheaply, which may be good for the excavation company, but this can result in excessive disposal bills for the client. It should also be mentioned that the contractor or site superintendent may not always volunteer to the client that additional sampling can be conducted to reduce excavation size.

> Plans to excavate a DDT site at a Naval Air Station in southern Florida were under development, and a round of delineation sampling had been completed. The sample team leader recommended to the site superintendent that additional sampling be conducted to reduce the area of excavation, and pointed out that the cost of sampling was very small compared to disposal cost. The superintendent informed the sample team leader that he was no longer needed on the project, and that he was not to speak to station personnel overseeing the operation.

At the end of this section, you will be familiar with methods for evaluating cost of sampling versus costs of excavation. A mathematical equation will be derived for this evaluation, which may be used in an Excel spreadsheet. You will be able to determine the degree of sampling that is beneficial, and avoid the pitfalls described in the two examples at the beginning of this section.

4.2. – Develop Method for Evaluating Sampling vs Excavation

In this section we will develop an equation for evaluating the cost of sampling vs excavation for excavation plans. For a given area of contaminated soil that has been sampled on a grid pattern, along the boundaries there will be a certain distance between the clean and contaminated sample locations, depending on the size of the grid. For example, for a 50-foot grid, there would be 50 feet distance between the clean and contaminated sample locations. Rather than excavate the whole grid, one could "estimate" a boundary halfway between, excavate, and sample after excavation. However, this could result in over- or under-excavating the grid.

Alternatively, one can collect a sample halfway between the contaminated and clean locations in an attempt to cut the grid excavation area in half. The area of excavation is cut in half, however, only if the sample is clean. In any case, one now has a 25-ft distance between the clean and contaminated location. This process can be repeated, to refine the boundary down to a desired distance, as long as the process is beneficial (saving the project money).

To further evaluate this process, let us consider the conceptual model illustrated in **Figure 8.** Starting with the initial grid, let us suppose we collected successive rounds of sampling, each time cutting the distance between the clean and contaminated location in half. We will later assign a probability to a given sample turning up contaminate or clean, but let us ignore that for now.

The first round of samples cuts the grid area in half. The second round cuts the remaining area between the known contaminated and clean location in half. For each new round of sampling, the area between contaminated and clean data points decreases, rapidly at first, but at an exponentially diminishing rate. This can be shown by the equation

$$\mathbf{A = G^{2^{(1-2^{-n})}}}$$

Where **G** is the initial grid area, assumed contaminated, **n** is number of additional sampling rounds, and **A** is the area taken away from the grid or excavation area.

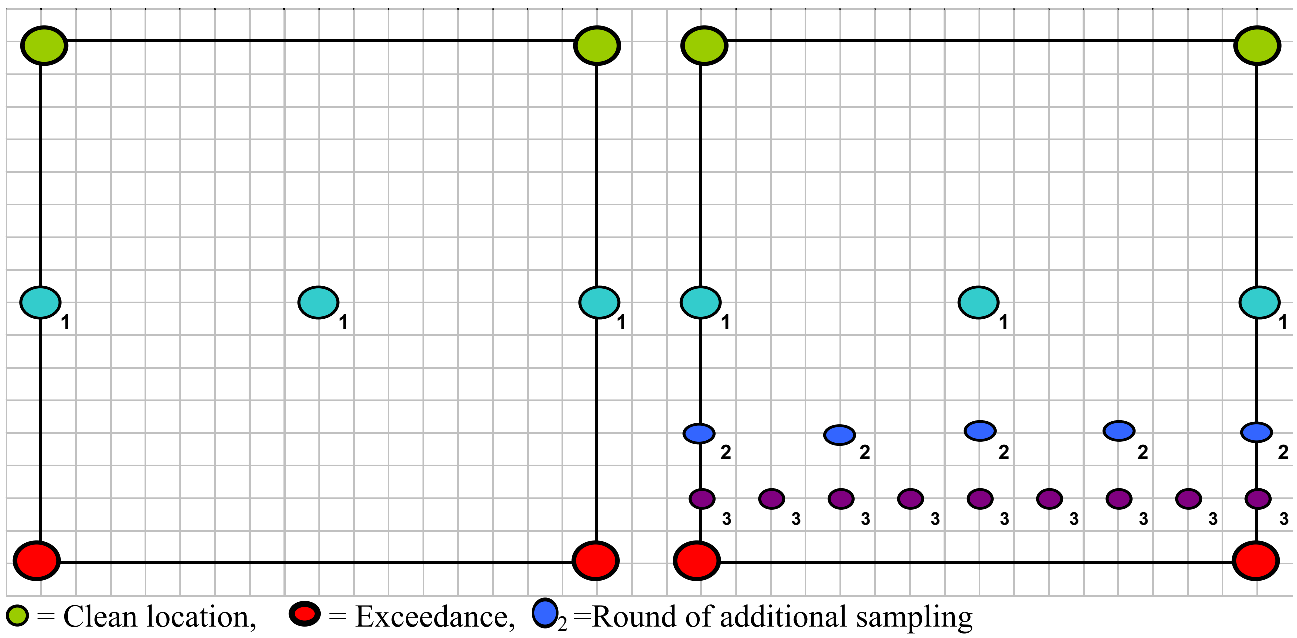


Figure 8: Conceptual model illustrating successive rounds of grid sampling (round 1-3) to reduce distance between clean and contaminated sample locations.

If one knows the excavation and disposal costs **(DC)** per volume of soil (i.e., cost/cubic yard), then, for a given depth, the reduction in cost, or cost savings, for each additional round of sampling, can be shown as follows:

$$\textbf{Savings} = \left(G^{2^{(1-2^{-n})}}\right) \textbf{DC}$$

However, the cost savings only occurs if a given sample result is below cleanup criteria. Therefore, we need to assign a probability that a given sample result will be above or below cleanup standards. Absent any better information, we will assign a probability of 0.5 that, on average, a given sample will be below cleanup standards. Field experience has shown that this tends to agree with field results for these types of boundary situations.

$$\textbf{Savings} = 0.5 \left(G^{2^{(1-2^{-n})}}\right) \textbf{DC}$$

Now we need to look at sampling costs. If we follow the pattern shown in Figure 8, for each additional round of sampling, the number of samples (**N**) tends to double, or grow exponentially.

This can be shown by the following equation:

$$N = 2^{2(1+n)-2}$$

Knowing the sampling cost, including labor and all associated costs per sample (**SC**), then the cost for additional rounds of sampling are:

$$\text{Cost for additional sampling} = \left(2^{2(1+n)-2}\right)SC$$

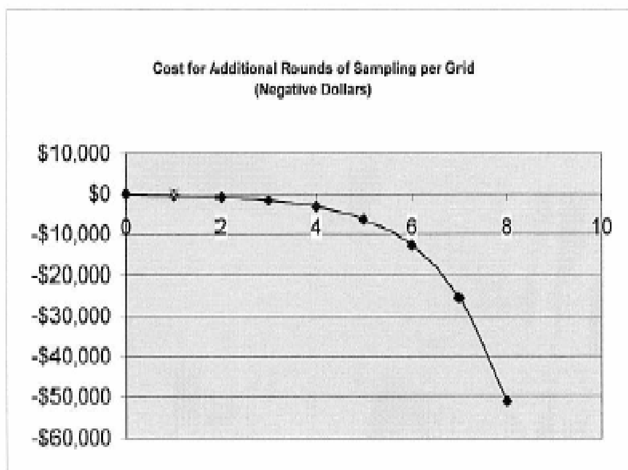
The equation for cost of additional sampling and the equation for cost saving due to reduced excavation, can each be graphed as shown in **Figure 9**.

0.5G^2(1-2^-n)DC - (2^(1+n)-2)SC

Savings from reduced excavation area - Cost for additional sampling

Grid Size	100
Removall Costs $/CYD	$200.00
Sampling Costs	$200.00
Depth of Excavation	1

Number of Iterations	Distance Between Samples	Sampling $ per Iteration	Cumulative Costs (per grid)
0	100.00	$0	$0
1	50.00	-$400	-$400
2	25.00	-$800	-$1,200
3	12.50	-$1,600	-$2,800
4	6.25	-$3,200	-$6,000
5	3.13	-$6,400	-$12,400
6	1.56	-$12,800	-$25,200
7	0.78	-$25,600	-$50,800
8	0.39	-$51,200	-$102,000



Grid Size	100
Excavation & Disposal	$200.00
Sampling Costs	$200.00
Depth of Excavation	1

Number of Iterations	Distance Between Samples	Disposal saving per Iteration (per grid)	Cumulative Cost Saving (per grid)
0	100.00	$0	$0
1	50.00	$18,519	$18,519
2	25.00	$9,259	$27,778
3	12.50	$4,630	$32,407
4	6.25	$2,315	$34,722
5	3.13	$1,157	$35,880
6	1.56	$579	$36,458
7	0.78	$289	$36,748
8	0.39	$145	$36,892

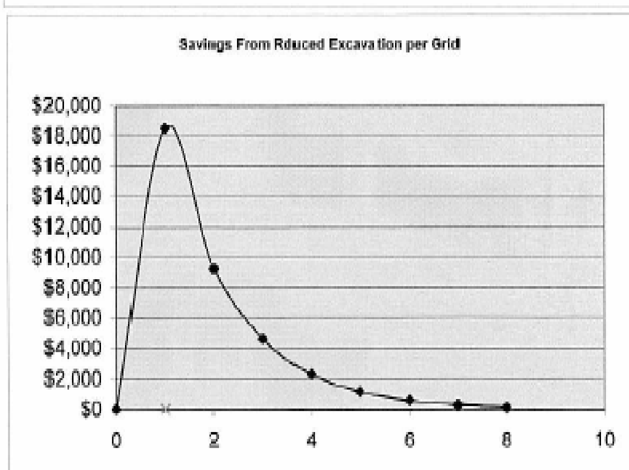


FIGURE 9 Exponential curves for cost of sampling and savings from additional sampling

If we now take our cost savings for each additional round of sampling, and subtract the cost of the additional sampling, we get the following equation:

$$\textbf{Overall Cost Savings} = 0.5\left(G^{2^{(1-2^{-n})}}\right)DC - \left(2^{2(1+n)-2}\right)SC$$

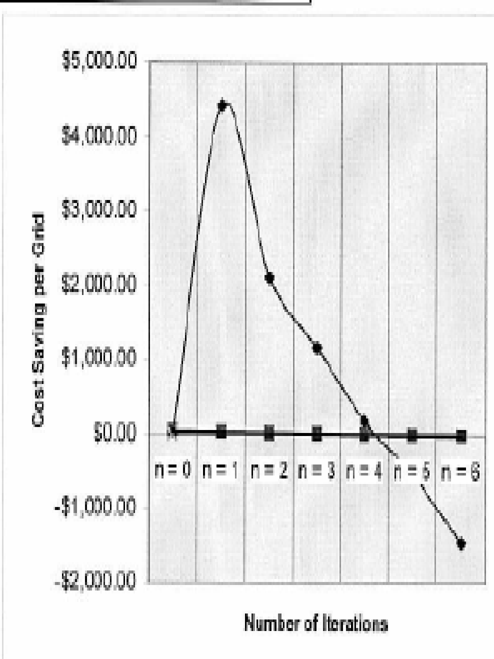
The equation can be incorporated in a worksheet and graphed in various ways, as shown in **Figure 10,** in order to easily determine a reasonable amount of refinement that should be performed on planned excavation.

Grid Size	50 ft
Excavation & Disposal Costs $/CYD	$200.00
Sampling Costs	$200.00
Sample Interval	1 ft
Depth of Excavation	1 ft
Above Grid Cost=	$18,518.52

Boundary Grids (Per Grid)

Number of Iterations	Distance Between Samples	Cost Saving per Iteration	Cumulative Cost Saving	Total Cost/Grid
n = 0	50.00	$0.00	$0.00	$18,518.52
n = 1	25.00	$4,429.63	$4,429.63	$14,088.89
n = 2	12.50	$2,114.81	$6,544.44	$11,974.07
n = 3	6.25	$1,157.41	$7,701.85	$10,816.67
n = 4	3.13	$178.70	$7,880.56	$10,637.96
n = 5	1.56	-$510.65	$7,369.91	$11,148.61
n = 6	0.78	-$1,455.32	$5,914.58	$12,603.94

Break Even Grid Size =	7.35 ft2
Area =	54.00 ft2
Volume =	54.00 ft3
Volume =	2.00 cyd
Break Even Grid Cost=	$400.00



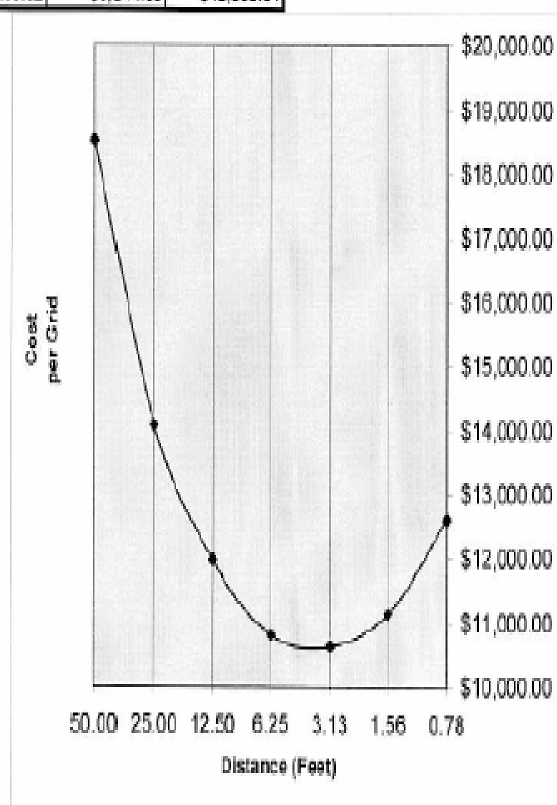


Figure 10: Worksheet above combines the equations from Figure 8 in order to optimize the degree of refinement that should be done to define excavation boundaries.

Let us look at the following case study: A PCB-contaminated wetlands area was initially delineated on a 50-foot grid. The site was found to be about two acres in area and contained concentrations ranging from 1 ppm to over 800 ppm PCBs and was limited to the upper one ft or less of soil. The cleanup goal was 1 ppm PCBs. An on-site landfill was being used for non-hazardous soil disposal, at a cost of about only $12/ton ($20/cyd), provided the soil was less than 50 ppm PCBs. Soil above 50 ppm had to be transported to an off-site TASCA landfill at about $200 a ton. Field analysis cost only about $50/sample, including labor. Previous practice had been to excavate based on this information, largely because the cost of on-site disposal seemed minimal verses additional delineation work.

Based on a cost/benefit analysis, however, additional rounds of sampling were performed prior to excavation. The outer boundary of 1 ppm PCBs was refined down to a 12-foot grid size. Inside this defined area, the 50-ppm boundary was located and sampling conducted to refine the 50-ppm boundary to within six feet. Cost savings was about $75,000 based on the original plan.

4.3 Compliance Averaging

Compliance averaging, to some degree, is almost always allowable in most federal and state regulatory jurisdictions. An example might be a 25-foot grid square where five samples have been collected, one or two of the samples are marginal exceedances, but the average for the grid square meets cleanup goals. In this instance the grid would be considered to have met cleanup goals **(See Figure 11**). Rules for using compliance averaging vary from jurisdiction to jurisdiction. Some states do not allow "non-detects" to be used for averaging, for example. Compliance averaging typically applies to sites after excavation, but is also applicable in many instances before excavation and can be built into the excavation plan. EPA's *Methods for Evaluating the Attainment of Cleanup Standards* (EPA, 1989) details a number of statistical methods for determining the mean or average concentration across a site. The use of compliance averaging should be negotiated with the applicable regulatory agency representative, or otherwise understood as it can be applied to your particular site.

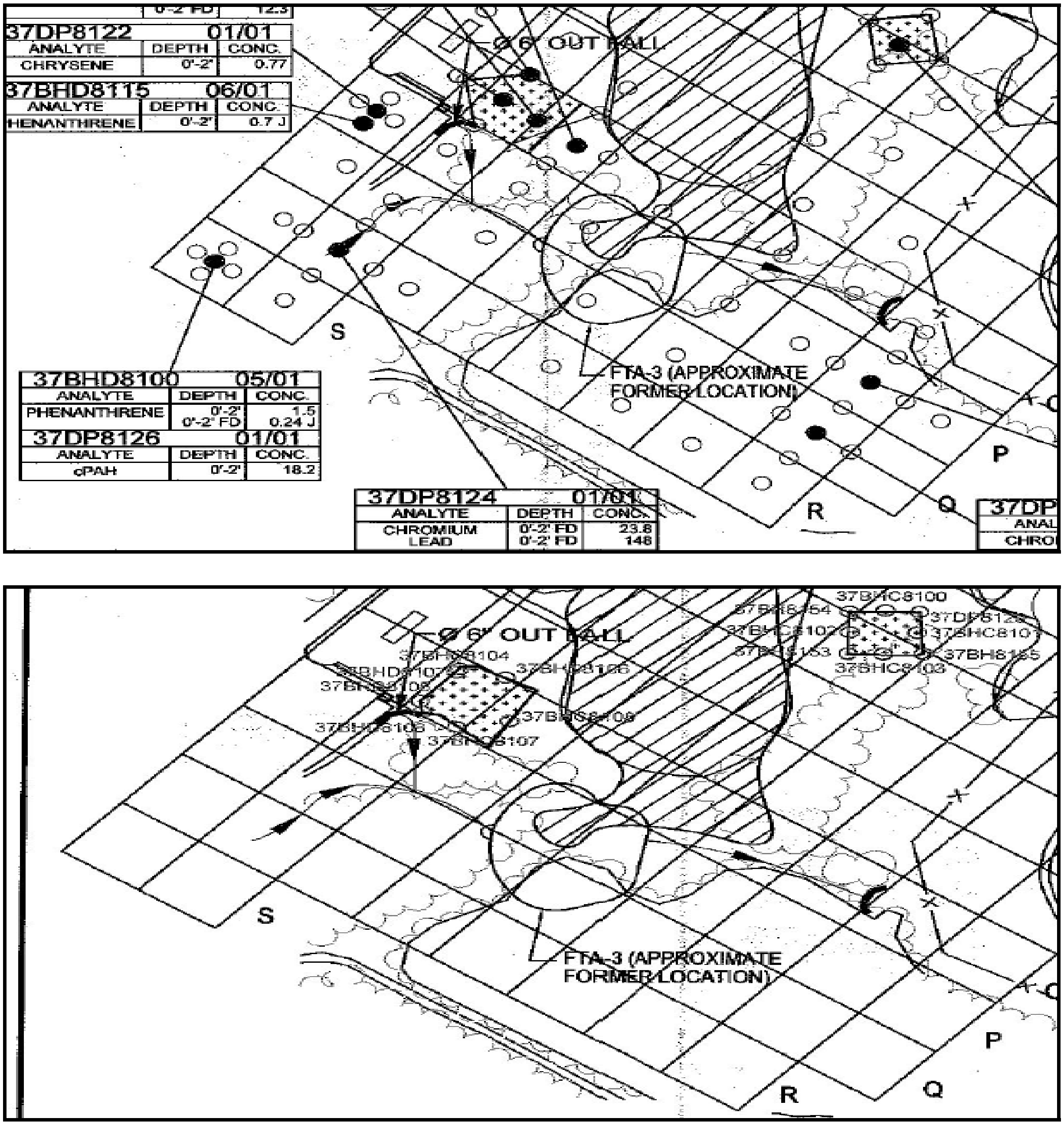


FIGURE 11: Example of compliance averaging where the preliminary excavation plan showed marginal exceedances at various grids in rows P, Q, R, & S.

<u>Top:</u> After additional sampling, data indicated the average concentrations for these grids were in compliance with cleanup criteria.
<u>Bottom:</u> Final excavation boundaries

The following are examples of situations where compliance averaging was designed into the excavation plan prior to excavation:

The first case is a site in an industrial setting, which had a cleanup goal of 10 ppm of a particular contaminant. Data showed the contaminants were generally widespread, over about three acres. However, about 80% of the contamination was in three areas that represented only about 10% of the site. An additional 16% of site contamination was in another 30% of the site. In this case 96% of the site contamination could be removed by excavating 40% of the site, and the average concentration across the site would fall well below cleanup goals for the site. The excavation plan was developed to meet this objective, and was approved by regulators.

A second situation is a site that had cleanup goals for various inorganics, pesticides, and PCBs. The inorganic values were based on published background values. The site consisted of about 20 grids that were 100 feet by 100 feet. The excavation plan was evaluated by simulating an excavation scenario that would remove one grid at a time, starting from highest to lowest in concentration. After each removal, the average site concentration was calculated for the remaining grids (cleaned up grids were not used in the averaging). After about 10 of the grids were eliminated, the average for the remaining contaminated grids fell below cleanup goals for the site. This was primarily because the remaining exceedances were for various inorganic analytes at or near background values. An examination of these grids showed that one grid would exceed chromium, the next would exceed nickel but not chromium, and the next would exceed copper but not chromium or nickel. Taken together and averaged, the remaining grids met the cleanup goals for the site.

Another situation would be isolated exceedances that are separate from the primary excavation area. In this instance it may be allowable to collect two to four additional samples nearby, say within a ten-foot radius, and calculate the average for the location. If the average is below cleanup standards, this is adequate in most cases to show compliance with cleanup standards.

5. Site Closure Sampling

Before the site is backfilled, adequate sampling of sufficient numbers and quality to satisfy regulator concerns is required. This sampling is referred to as confirmation or verification sampling. There are a number of different approaches to site confirmation sampling.

The often referenced EPA document *Methods for Evaluating the Attainment of Cleanup Standards, Volume I: Soils and Solid Media* (EPA, 1989) details numerous statistical approaches for determining the attainment of cleanup standards within given probabilities. The methods detailed in this document tend to be difficult if not impossible for many people to understand, and are generally overly complicated with respect to what is generally considered adequate for most remedial excavations. EPA later issued a second document entitled, *An Overview for Methods for Evaluating the Attainment of Cleanup Standards for Soils, Solid Media, and Groundwater, EPA Volumes 1, 2, and 3* (EPA, 1996), which clarifies that the first document should not be used as a cookbook that must be followed without question. It concluded that the best approach is for team members and regulators to work together as a team to determine the appropriate data-gathering and evaluation process to assure cleanup objectives are met.

Another, less complicated document that provides guidance on this subject is a State of Michigan guidance document *Verification of Soil Remediation* (DEQ, April, 1994). This document provide methods for determining grid size and the minimum number of confirmation samples for a given excavation area and sidewall length. Another good document is the State of Wyoming *Soil Confirmation Sampling under Voluntary Remediation Program* (05/09/03). Yet another document that provides a simple common sense approach for determining average site contaminant levels (exposure point concentration) is the Commonwealth of Massachusetts *Guidance for Disposal Site Risk Characterization in Support of the Massachusetts Contingency Plan* (MADEP, July 1995) Section 5.8 and Section 7.3.3.6. The focus of this document is site risk characterization rather than verification sampling per se, but it provides a usable framework for determining average contaminant levels across the site.

Another approach is to grid the site and conduct verification sampling based on "hot spot" detection; in other words, based on the probability to detect an area of residual contamination of a certain size or shape within the site. This topic is covered under section 9 of the EPA's *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1* (EPA, 1989). The size of an area of residual contamination that would be considered unacceptable is determined, and the grid is designed to detect an area of that size or greater, within an acceptable probability.

A simplified variation of this approach is to size a grid such that it will detect a contaminated area of 10% or more the area of the excavation. In other words, if the excavation is 1,000 square feet, the grid would detect a contaminated area of 100 square feet (or larger). Such a "hot spot" would have a radius of about 18 ft. Under this method, grid size is base on the square feet of the excavation, and the number of samples tends to be 11 to 12 regardless of the size of the excavation.

One of the complaints against many of the statistical methods for site verification sampling is that they tend to "wipe the slate clean" and approach the site almost as if no previous samples had been collected. These methods sometime tend to ignore the body of knowledge gained at a site from extensive pre-excavation sampling and samples collected during excavation. Most regulatory jurisdictions will work with the cleanup party and concur with the site confirmation sampling plans if the plan provides a reasonable assurance that cleanup goals have been attained. For example, if field analytical methods have been used to collect extensive data on the bottom of an excavation, one may propose collecting a limited number of off-site laboratory samples to verify and bolster the existing data set for the site.

The following method is desirable when the excavation encroaches or interrupts the function of a critical infrastructure or utility service. In order to minimize the interruption, samples are collected to located clean boundaries, and adequate off-site confirmation samples are collected at the depth of the clean bottom and side boundaries of the planned excavation prior to excavation. The excavation is then performed and extended to the clean sample point locations. At the completion of the excavation, the verification data have already been collected, and there is no need to re-sample the same locations. This allows the excavators to go in once and complete the excavation and backfill in an efficient manner. This approach may also be used in routine cleanup excavations, depending on site-specific conditions and regulator input.

6. Site Restoration, Reports, and Contracting

A detailed discussion of site restoration, reports, and contracting is beyond the scope of this course. A brief discussion of these topics is provided below.

6.1 Site Restoration

Most contracts specify restoring the site to pre-excavation conditions as a boilerplate item, and this typically involves backfilling to original grade, applying topsoil, and seeding the area for grass. One may want to consider other alternatives, however, if appropriate for the site. For

example, it may be allowable to regrade the area with nearby material rather than hauling in fill material. For ditches, it may not be necessary to backfill, as long as erosion concerns are addressed. For wetland or wetland boundary areas, the possibility of leaving an open water area as an alternative to backfilling may be an acceptable alternative. Open water areas can provide a beneficial habitat for wading birds and enhance the ecology of the surrounding wetlands.

6.2 Close Out Reports

After excavation and restoration activities are complete, many jurisdictions require a final inspection by a regulator or equivalent representative. After this is completed, the next step is to issue a closeout report to document the activities and results of the cleanup operation. The term "closeout report" is used generically here, as these documents go by different names, depending on the regulatory jurisdiction of the cleanup activity. Guidance for site closure reports is available in the EPA document *Closeout Procedures for National Priorities List Sites* (EPA, Jan. 2000) for sites regulated under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and listed on the National Priorities List. For "Non-Time Critical Removal Actions" under CERCLA, the requirement for a closure, or remedial action report, is not stated. Concurrence that the action has been completed should be obtained from the appropriate regulatory agency. For sites closed under state regulations, the format or guidance specific to that state should be consulted, including any time line requirements that may be applicable.

6.3 Contracting

The following approach should be avoided: A typical facility manager, knowing that a number of sites need to be excavated, may logically award a contract to a typical excavation/construction type contractor to perform the job. A good excavation contractor usually tries to move lots of dirt quickly and efficiently. The excavation crew shows up, and a sample crew is brought in to support the excavation. The excavation work proceeds ahead of the sampling effort, and has to slow down or go on standby time while the sampling and analytical work plays catch up. Adjustments are made and the excavation contractor gets back to moving lots of dirt, with follow-on sampling to determine if all the contaminated soil is removed from a given area. Moving lots of dirt may be beneficial to the excavation contractor, but this results in a rapidly growing waste disposal bill. This approach typically results in over-excavation of areas and ultimately a higher disposal cost for the project.

Contracting should be set up to accommodate the general approach described in this course. Adequate sampling capability needs be available early on and throughout the effort. Environmental engineering support should be available to develop the preliminary excavation plan, and to refine excavation boundaries prior to excavation. The schedule should be flexible, if possible, to accommodate a management review of the cleanup strategy and changes in treatment /disposal alternative, if appropriate. A detailed excavation plan should be in place before the excavation contractor is brought in.

7.0 Course Summary

The importance of appropriate management of contaminated soil removal operations is often greatly underestimated because of the perceived simplicity of the operation. Experience has shown that management should follow a systematic approach that includes the following elements: (1) Grid and sample the site to verify true boundaries and develop a preliminary excavation plan, (2) Perform a management review of cleanup strategy based on increased knowledge of the site and currently available options, and (3) Refine and optimize the excavation plan to minimize removal costs.

Keep in mind that the RI/FS or equivalent document almost never provides adequate information to proceed with excavation in an efficient manner, and the average facilities manager is not going to automatically know this. Always grid and sample the site, or otherwise verify the true boundaries of excavation, including depth, prior to excavation activities. Do not assume the selected remedial alternative is a forgone conclusion. If the site or volume of soil is different then expected, or even if it is not, do a reality check of treatment or disposal options. Re-evaluate cleanup strategy based on increased knowledge of the site, current conditions, and disposal options, and modify the approach if appropriate. When it is determined that excavation is the preferred remedial method, develop and refine the excavation plan to reduce excavation size. If nothing else, avoid a possible quagmire by determining the outer boundary of excavation before starting. Contracts should be structured to accommodate the approach described in this course. Assure adequate sampling to verify site conditions and reduce excavation cost. Schedules should be flexible, if possible, to accommodate planning and adjustments to cleanup approach.

8.0 References

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