Project Work Plan

Refine Location of the Chromium Source at the 100-D Area and Support a Geochemical/Mineralogical Study of Chromium in the Vadose Zone

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1.0 INTRODUCTION

Sodium Dichromate was used in the reactor cooling systems (at approximately 1000 ppb hexavalent chromium) to retard corrosion in metal pipes. The chemical was delivered to water treatment plants in bags, rail cars, barrels, and through local pipelines in a stock solution that was up to 25 wt. % hexavalent chromium. Inevitably, some of this chemical was spilled during handling and/or leaked from the pipelines, and migrated through the vadose zone to the groundwater. These spills probably occurred during the operation period of the DR reactor (1950 to 1964), so the chromium could have been spilled over 50 years ago. The chromium was likely driven the 80 ft through the vadose zone by natural precipitation, perhaps assisted by leaks in buried water lines or concentrated runoff from roads or buildings.

The southwestern chromium plume in Hanford's 100-D Area is currently being treated by the In Situ Redox Manipulation permeable reactive barrier (ISRM) to intercept chromium before it enters the river. Concentrations in the plume upgradient of ISRM have remained high since the plume was first discovered in 1999, which strongly suggests that there is a source of chromium in the vadose zone. The fact that chromium concentrations in the groundwater have been measured above 4000 ppb establishes that the source is not cooling water itself, but a considerably more concentrated solution.

Records of spills were generally not kept during the production years, so locating the site of these spills must be done directly. Several likely source locations have been identified and investigated since 1999. The most intensely characterized area to date has been the site of the 183-DR Head House, where water conditioning chemicals were handled. This facility was demolished in 1978. Two boreholes were drilled and several deep trenches excavated in 2000, in an attempt to find chromium in the vadose zone. Samples were also obtained from surface soils and test pits excavated in 2004 near the suspected source. These efforts were not successful in finding elevated chromium in the vadose zone, although low levels (< 4 mg/kg) were found in a few areas near the surface (BHI 2004).

Subsurface access is very poor in the suspected source area because much of the top 10-15 ft consists of construction debris, including buried foundations and rubble from demolished buildings. Thus, subsurface access and sampling using cost-effective push technology, which has been attempted in this area, would probably not be successful. The source could be very localized, so finding small spills in the vadose zone using conventional characterization technology is problematic. Since small subsurface spills are difficult to locate in the vadose, there are two general methods that would be useful for locating a chromium source. One is characterizing groundwater at the head of the plume, using conventional or innovative drilling techniques (such as the Enhanced Access Penetration System) to identify the most concentrated and/or furthest upgradient portion of the groundwater plume. Groundwater monitoring at several points would help define the head of the ISRM plume. This information would refine the general location of the vadose source, which should help the River Corridor Contractor focus their excavation work and help the Groundwater Remediation Project develop alternative remedial technologies for the remediation of the source area (e.g. apply calcium polysulfide to the subsurface).The other method is to indirectly locate either the proximal portion of the groundwater plume or a chromium source in the vadose zone using geophysical techniques. This latter method has been evaluated by a panel of experts, who determined that there was a low probability that any surface geophysical method could directly detect low levels of chromate in the vadose zone. Therefore, this work will focus on obtaining soil samples from the vadose zone to analyze in the laboratory. A complimentary task will be refining the location of the chromium source by collecting groundwater from the same subsurface access points.

2.0 WORK DESCRIPTION

The objectives of this work are to obtain soil samples from the suspected source area for the southwestern 100-D Area chromate plume, and refine the source location by collecting groundwater samples. The vadose zone samples will be collected to support the work on geochemical form and behavior of chromium (described in the companion PNNL proposal). The groundwater samples will be used to refine the location of the proximal portion of the southwestern chromium groundwater plume in the 100-D Area.

This work is an integral part of the systems approach to reduce the mass of chromium contamination, continue to protect the river, and accelerate remediation. As part of this work, an evaluation of cost-effective innovative drilling and sampling technologies will be conducted to ensure the appropriate technologies will be deployed to meet the objectives of the investigation. Selection of the technology used to collect samples will be made through a competitive bidding process. The use of innovative drilling technologies will be encouraged. The requisite soil and groundwater samples could be obtained using small-diameter drilling equipment, which may be significantly less costly to deploy and utilize than more traditional drilling techniques (e.g., cable tool). Descriptions of two small-diameter drilling technologies that have recently been successfully tested in the 100 Areas are presented below.

2.1. Small-Diameter Drilling Technologies

Subsurface soils in Hanford's 100 Areas provide a challenging environment for drilling, especially for technologies that rely exclusively on pushing cone-tipped rods into the subsurface. The Hanford formation is composed predominately of sands and gravels, with gravel clasts ranging from pebbles to boulders in size. Conventional cone penetrometry (CPT) and Geoprobe® have been deployed in the 100-D area, but have rarely been successful. When the cone-tipped rods encounter a gravel clast larger than approximately 5 cm in diameter, even 30 tons of static force is not sufficient to either break the clast or shove it aside. In addition to the natural impediments, much of the area where the chromium source is thought to be located is underlain by debris left behind after the 183-DR Head House was demolished. These materials consist of large blocks of steel-reinforced concrete which could challenge even conventional drilling techniques.

Another factor to consider with small-diameter systems is that groundwater sampling wells will not meet requirements set by the Washington State Department of Ecology (Ecology). The Washington Administrative Code WAC-173-160-450 requires an annular seal at least 2 in thick (e.g., an 8-in diameter borehole could accept a well casing with an outside diameter no greater than 4 in). By definition, no small-diameter drilling technique can comply with this requirement, so a variance will be required to complete groundwater wells using this technology.

Recent advances in small-diameter drilling technologies provide encouragement that access to the subsurface in the 100 Areas could be obtained more cost-effectively than using conventional drilling techniques. Two of these technologies, the Enhanced Access Penetration System and Hydraulic Hammer Rig, are discussed below.

2.1.1. Enhanced Access Penetration System

The Enhanced Access Penetration System (EAPS) consists of a CPT with the capability of drilling with an air-rotary system (Figure 1). This technology was developed specifically to access the deep vadose zone in the 200-W Area in order to characterize carbon tetrachloride. The technology was successfully used in the 100-D Area in 2003 to install a small-diameter groundwater sampling well.

Figure 1. The Enhanced Access Penetration System Showing the Cone Penetrometer and Drilling Head.

The system works by hydraulically pushing a cone-tipped rod into the ground until an underground obstruction (such as a large rock, or a layer of hard sediment) halts progress. This is as deep as a conventional CPT can go, but the EAPS can deploy a small drill through the middle of the CPT rods and drill through the obstruction. If softer layers are present below the obstruction the system can switch back to direct pushing. One advantage of pushing instead of drilling is that no wastes are brought to the surface, which eliminates waste handling, storing, and disposal concerns. This feature, combined with other advantages of CPT (less expensive and faster than conventional drilling techniques), make this the technology of choice for applications where soil or gas samples need to be collected from the shallow to intermediate vadose zone.

2.1.2. Hydraulic Hammer Rig Description

The Hydraulic Hammer (HHR) drilling system was specifically designed by Duratek Technical Services as a subsurface access technology for use in the Hanford Site Tank Farms. The system is designed to advance 2.625-in OD by 1.75-in ID rods using a solid drill tip with a hydraulic drive system capable of rotating the rods. The rods are advanced to the sampling depth using a combination of percussive drilling and rod rotation as needed to shove obstructing material to the side. Samples are collected through the use of a dual rod approach so multiple samples can be collected during a single penetration. The HHR has been successfully tested in Hanford's 200-W area and has been used to install several wells at 100-N.

Figure 2. The Hydraulic Hammer Rig.

3.0 PROJECT SCOPE

The following work elements are proposed to accomplish the objectives.

3.1. Task 1. Project Management

Tasks includes the labor for planning, management, supervision, attending safety meetings, responding to specific DOE-RL requests, interfacing with DOE-RL and the regulators, and oversight of all activities.

3.2. Task 2. Work Plan

The Work Plan will detail the objectives and performance criteria for the work, as well as the scope and schedule. The Work Plan will also specify the number and placement of the boreholes, and will include a sampling and analysis plan, which will require regulatory approval.

3.3. Task 3. Sample Collection

The main goal of this task is to collect representative vadose zone and groundwater samples in the area suspected to contain the source of chromium supplying the plume. This work will be guided by the sampling and analysis plan (Task 2).

Approximately 7 wells will be drilled near the site of the 183-DR Head House to refine the source area location. Samples will be periodically collected from the vadose zone and submitted to PNNL for laboratory analysis. Both systematic and judgment samples will be collected. The wells will be at least temporarily completed to monitor groundwater. Also included in this task is planning for the field work which, among other things, involves obtaining an excavation permit and a contractor for drilling and sampling.

3.4. Task 4. Groundwater Monitoring

Groundwater will be collected weekly through the course of this project and analyzed in a field laboratory. Samples collected immediately after drilling will be treated as suspect, because drilling is likely to cause a localized area of reduction in the aquifer. This should dissipate within a month as oxic groundwater flows through the area under natural gradient conditions.

3.5. Task 5. Evaluation Report

A report evaluating the soil and groundwater data collected during the course of this work will be prepared under this task. Part of this report will be a modeling and statistical study that will focus on refining the source of chromium in the area. The modeling will use the groundwater chromium data, coupled with analysis of groundwater flow in the area, to refine a conceptual model for chromium in the vadose zone and groundwater. The dynamic nature of groundwater flow will be considered, using hourly measurements of groundwater levels collected by an automated system. This system is already in place on the Hanford Site, relaying data remotely.

Once the area of the chromium source is located, a couple different remediation technologies could be applied to reduce it. The first is infiltration of a liquid reductant (e.g., calcium polysulfide) through a drainage field constructed above the source area. This technique as been successfully applied in other areas with chromate contamination. Another technology for reducing hexavalent chromium to trivalent chromium is infusion of a strongly reducing gas (e.g., hydrogen sulfide) into the vadose zone. This technology has been successfully tested at the White Sands Missile Range (Thornton 1999). Remediation is outside the scope of this work.

3.6. Major Deliverables and Dates

Transmit Decisional Draft Work Plan to RL	July 28, 2006
Complete Drilling	December 1, 2006
Transmit Decisional Draft Report to RL	September 28, 2007

3.7. Basis and Assumptions for Estimate

The following were used as guidance to formulate costs and schedules for this project. The schedule is presented in Figure 2.

- The project assumes that the authorization to proceed will occur by June 15, 2006
- The scope of the estimate is to drill wells to provide vadose zone samples to PNNL, and to collect groundwater in order to refine the location of the chromate source for the southwestern plume in the 100-D Area. Approximately ten wells will be drilled and sampled. Groundwater will be collected and analyzed throughout the course of this work on a regular basis.
- Well drilling will be performed by contractor(s)
- Wells will be decommissioned by the contractor(s)
- Cost of the well drilling is based on FY 2005 actuals
- Project Management task includes informal weekly status reports to RL, semiannual reviews by DOE-HQ
- Final (reviewed) report will be completed by the end of FY07

The following process was used for developing the preliminary cost estimates for this project:

- The estimate process began by identifying the steps required to perform the work described for this project.
- Assumptions were identified and activities were detailed into manageable tasks. Meetings were then conducted with management and engineering to validate tasks and assumptions
- The activities were resource loaded with the anticipated resources to accomplish the work. Labor was estimated by the Cost Account Manager and engineering personnel based on previous investigations.
- Estimate excludes planning of resource overtime
- Assumes that the amount of waste to be managed will be negligible

Total Budget: $650,000

4.0 REFERENCES

Thornton, E.C., J.T. Giblin, T.J Gilmore, K.B. Olsen, J.M. Phelan, and R.D. Miller. 1999. In Situ Gaseous Reduction Pilot Demonstration – Final Report, PNNL-12121, Pacific Northwest National Laboratory, Richland, WA.

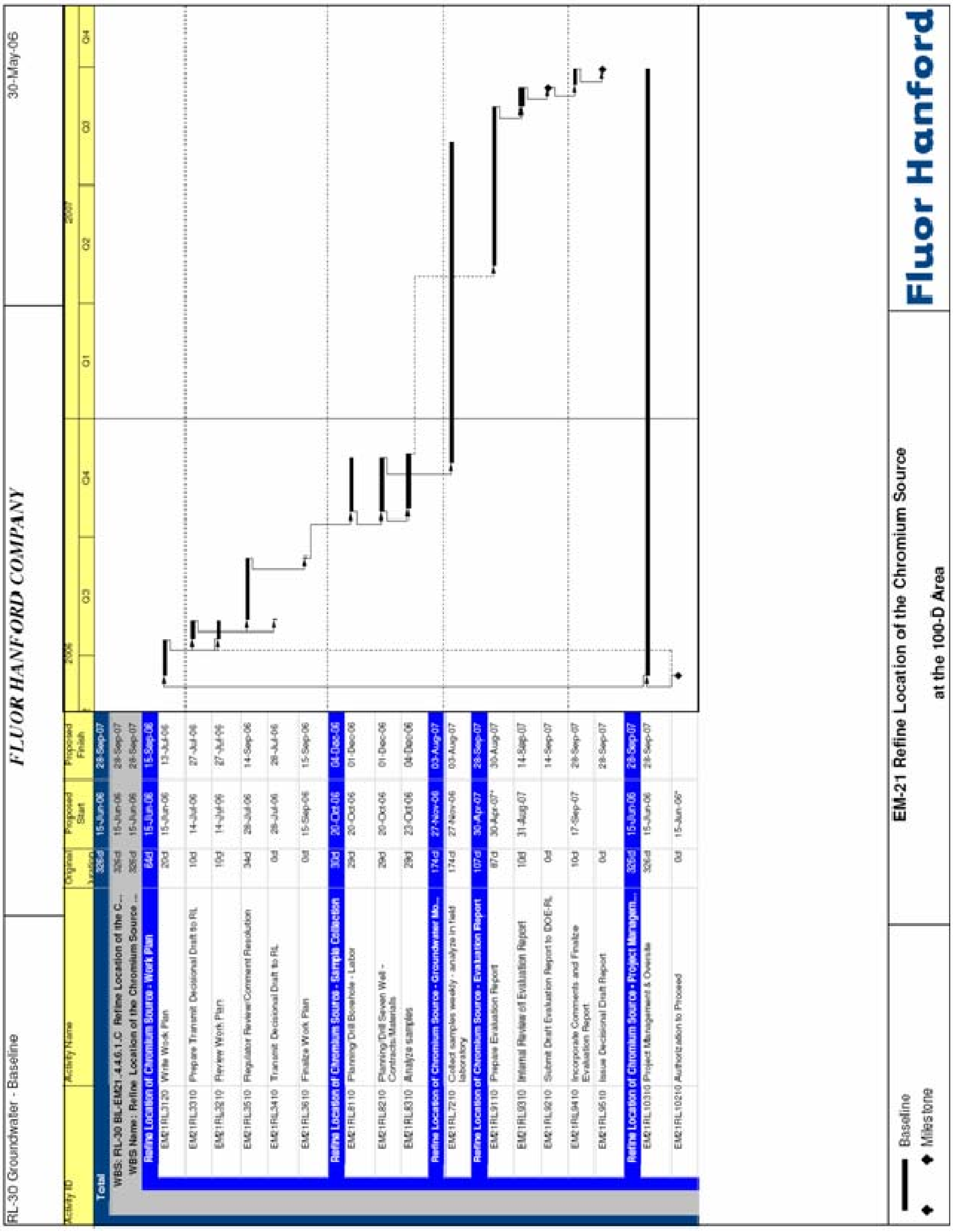

Figure 3. Work Schedule.

U.S. Department of Energy
Supplemental Columbia River Protection Activities Peer Review

Proposal Title: Refine Location of the Chromium Source at the 100-D Area

STATEMENT REGARDING RESPONSES: The attached proposals are extensive revisions of the original, and include many of the recommendations below. The geophysical approach has been abandoned and replaced with a detailed investigation of chromium geochemistry in the vadose zone. This is coupled with field work to gather samples for the laboratory study as well as groundwater samples to help establish the boundaries of the plume and refine the location of the source. The following responses to comments address some aspects of the original scope, but in some instances may not provide a complete answer because of the considerably revised approach to the problem.

Technical Basis of the Proposal:
The panel believes the proposed use of geophysics is not likely to achieve the desired outcome of directly identifying the chromium source in the 100-D Area. The most important and overarching themes of the panel recommendations are: 1) success of any source identification effort requires a clearer conceptualization of the expected nature and form of chromium in the source; and, 2) supplemental technology solutions should be developed and implemented based on their responsiveness and sensitivity to the expected nature of the source. Refining the conceptual model based on existing data and focused study is a prerequisite to successful source identification. As described below, the peer review panel does not endorse a source identification effort built primarily around geophysics in this setting, nor does the panel endorse an unconstrained brute force drilling and sampling program.

Geophysics will not be the "silver bullet" that directly locates the source of chromium contamination, but geophysics may be useful to enhance understanding of the stratigraphy of the vadose zone and may be able to identify areas or traps where the contamination is likely to exist. In order to effectively use geophysics to identify these traps, a better conceptualization of the nature of the controlling features and the source zones will be needed. (see reviewers 3,4,5, and 6)

The first step recommended is study of an area of known Cr contamination in the vadose zone to understand transport, fate, and form of Cr. Build a conceptual model for the 100-B Area Cr contamination and then test various geochemical and geophysical methods at this site of known contamination, prior to application of these methods at the 100-D Area. Use an integrated approach with multiple methods to provide "defense in depth." (see reviewers 2,3,4,5,6,7, and 8)

- **Response:** Agree in part. The proposal has been completely rewritten to address geochemical behavior of Cr in the vadose zone. The recommendation to apply geophysics to elucidate vadose zone structure and correlate chromate concentration is not in the revised proposal. It is felt that this approach would be expensive and time-consuming and results would be ambiguous. The combination of stratigraphic heterogeneity and uncertainty in the location of the original source at 100-D yields a low probability of success for finding anthropogenic chromium through the conceptual model approach defined above.

- Geophysical methods should include surface, borehole, and cross-borehole tomography using methods such as radar, seismic, and resistivity. SP measurements do not appear to be promising and have not been proven for this type of application. Geophysics can only be applied with sufficient geologic information to provide ground truthing. Consider adding exploration geochemistry methods if a suitable hypothesis and signal can be identified in the vicinity of the source zone.
  - **Response:** The revised approach does not include geophysical prospecting for Cr.

- Boreholes will first have to be drilled to obtain geologic samples for chemical (for Cr total, +3, and +6, because the solid form may be Cr+3, which is oxidized to Cr+6 as it dissolves into the pore water) and SEM analyses (map the Cr and validate identification of the form of the Cr) and for ground-truthing the geophysics.
  - **Response:** Agree. Borehole samples will be used for the laboratory studies, along with samples collected in the 100-BC Area.

- Past data should be reexamined to determine if there are any important issues associated with extraction efficiency of Cr(VI), if Cr(III) at high concentrations in a source zone may contribute low but stable levels of Cr(VI). A review process, along with the focused study of the 100-B site, would provide information about the potential "signals" expected in the source zone (both geophysical and geochemical) and would help in determining the appropriateness of potential source treatment alternatives.
  - **Response:** The revised proposal incorporates these ideas from a geochemical perspective.

- Boreholes should be geophysically logged (consider neutron logs and investigate other tools that can be used in cased holes) and install casing for cross-borehole tomography. Radar requires PVC casing, whereas seismic requires steel casing (and boreholes must be filled with water using FLUTe technology).
  - **Response:** Casing materials for newly drilled boreholes will be chosen to be compatible with geophysical tools required (i.e., PVC or fiberglass for electromagnetic techniques, steel for acoustical techniques).

- After identification of the form and structure of the Cr in 100-B, develop a clear conceptualization and a limited number of hypotheses about the nature of Cr sources in the Hanford setting near the Columbia River. Determine if there are alternative signals that can be identified, such as soil gas or push-pull testing. If so, collect soil gas samples either during drilling of additional boreholes or possibly from shallow sampling. Push-pull testing will require installation of screened vadose-zone monitoring points.

- **Response:** Application of alternative characterization techniques such as soil gas will be evaluated.

After the work is completed at the 100-B Area, a similar detailed site investigation should be conducted at the 100-D Area near the suspected source areas. This investigation should utilize the methods that were successfully applied at the 100-B Area (described above) and should include data necessary to construct a conceptual model for this location.

- At the 100-D Area, the goal of the site investigation to identify stratigraphic traps for the Cr could be very difficult to demonstrate as the entire section may consist of extremely coarse-grained materials, with sand as the finest grain size present.
  - **Response:** Using geophysics to elucidate stratigraphy is not in the current proposal.

- Consider using EAPS to reduce costs. Direct-push technology can provide continuous resistivity information.
  - **Response:** Alternatives to standard drilling technologies will be considered.

- Prior to drilling with EAPS, perform low-frequency ground-penetrating radar (GPR) surveys to locate large boulders that can then be avoided when identifying drill locations, and map cultural interferences that would also impact future geophysical surveys. GPR may be useful for mapping subsurface geology to 30-foot depth.
  - **Response:** Comment noted.

- In addition to the use of GPR for reconnaissance either prior to other surface geophysical surveys or drilling, use electromagnetic methods (e.g., EM-31), ground conductivity meter (GCM), or magnetic surveys.
  - **Response:** Comment noted.

Other alternatives that could be considered include:

- Further investigate impact of acidic chromate solutions on chemistry of soil, perhaps looking at uranium and daughter products. Obtain more information about the chemistry of the chromate solutions in terms of potential co-contaminants, pH, etc.
- Consider the use of forensic groundwater/vadose zone modeling to better define the source locations.
- Consider tracer testing to enhance the conceptual model of subsurface migration of contaminants.
- Consider application of induced-neutron gamma ray spectroscopy (e.g., Herron and Herron, 1996) to obtain high-resolution geochemical logs of cased holes. These data can typically be utilized to infer formation lithology and possibly hydrogeological parameters. However, formation lithology data may not be that useful at the 100-D Area, as the entire section will be very similar mineralogically and will contain primarily quartz.
  - **Response:** Comments noted.

Implementation Strategy:
The proposal calls for convening an expert panel to recommend geophysical methods for direct detection of Cr. This activity is not recommended since it duplicates efforts of a previous panel that stated that geophysics could not be used to directly detect Cr in soils, especially given the current understanding of the geology of the vadose zone. This review panel supports the findings of the earlier panel and recommends that this proposal not be supported as written.

If a new proposal is prepared, it should be peer reviewed, including evaluation of the implementation strategy.

The panel recommends a phased approach, beginning with investigation of a known chromium source area, testing of methods for detection, and later application at the 100-D Area.

- o **Response:** The revised proposal details a geochemical investigation to determine the physiochemical forms of Cr and their solubilities, using soil samples excavated from the 100-BC and 100-D Areas.

The panel also recommends an integrated strategy that involves use of multiple methods, including geophysics and geochemistry to build the conceptual model. "Defense in depth" is required to ensure better success in the face of this challenging problem.

- o **Response:** As stated above, it is the opinion of site personnel that acquiring geophysical data would not be cost-effective, owing to the heterogeneous character of the vadose zone.

Proposed Performance Metrics:

- Performance metrics are not specifically included in the proposal. A more detailed description of specific performance objectives is needed.
  - **Response:** Agree

- If a new proposal is prepared, it should be peer reviewed for proposed performance metrics.
  - **Response:** This will be decided by DOE personnel.

- Specific and clear performance metrics must be developed to make this project a success. Better definition of what is a Cr source is desirable.
  - **Response:** Agree