Observational Approach to Chromium Site Remediation – 13266

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ABSTRACT

Production reactors at the U.S. Department of Energy's (DOE) Hanford Site in Richland, Washington, required massive quantities of water for reactor cooling and material processing. To reduce corrosion and the build-up of scale in pipelines and cooling systems, sodium dichromate was added to the water feedstock. Spills and other releases at the makeup facilities, as well as leaks from miles of pipelines, have led to numerous areas with chromium-contaminated soil and groundwater, threatening fish populations in the nearby Columbia River.

Pump-and-treat systems have been installed to remove chromium from the groundwater, but significant contamination remain in the soil column and poses a continuing threat to groundwater and the Columbia River. Washington Closure Hanford, DOE, and regulators are working on a team approach that implements the observational approach, a strategy for effectively dealing with the uncertainties inherent in subsurface conditions.

Remediation of large, complex waste sites at a federal facility is a daunting effort. It is particularly difficult to perform the work in an environment of rapid response to changing field and contamination conditions. The observational approach, developed by geotechnical engineers to accommodate the inherent uncertainties in subsurface conditions, is a powerful and appropriate method for site remediation. It offers a structured means of quickly moving into full remediation and responding to the variations and changing conditions inherent in waste site cleanups.

A number of significant factors, however, complicate the application of the observational approach for chromium site remediation. Conceptual models of contamination and site conditions are difficult to establish and get consensus on. Mid-stream revisions to the design of large excavations are time-consuming and costly. And regulatory constraints and contract performance incentives can be impediments to the flexible responses required under the observational approach.

The WCH project team is working closely with stakeholders and taking a number of steps to meet these challenges in a continuing effort to remediate chromium contaminated soil in an efficient and cost-effective manner.

INTRODUCTION

Nuclear material production at DOE's Hanford Site in Richland, Washington, required massive quantities of water for reactor cooling and material processing. For this reason, production reactors at the Hanford Site were built near the Columbia River and drew their cooling water from the river. To reduce corrosion and the build-up of scale in pipelines and cooling systems, sodium dichromate was added to the water feedstock. Over decades of operation leaks from pipelines, spills, and other releases at the makeup facilities led to numerous and extensive areas with chromium-contaminated soil and groundwater.

Cleaning up the chromium contamination in groundwater at the Hanford Site is a major priority for DOE. Over the last decade, the DOE has invested tens of millions of dollars to prevent chromium contamination from reaching the Columbia River and to remove the contamination from soil and groundwater. An extensive pump-and-treat system has been installed to intercept contaminated groundwater before it gets to the river.

In parallel to the groundwater treatment program, the DOE has aggressively pursued removal of contaminated soil that acts as a source for continued leaching of chromium into the groundwater. Washington Closure Hanford (WCH), a consortium of URS, Bechtel, and CH2M Hill, was formed to execute the DOE River Corridor Cleanup Contract and has performed remedial actions on a number of chromium-contaminated soil sites. During the last several years, WCH has excavated over 1 million tons of material in an effort to remove the source of continuing chromium contamination to the Columbia River.

Remediation of these chromium-contaminated areas has been conducted using the observational approach, a strategy for cleanup of Hanford waste sites adopted sitewide. A number of significant factors, however, complicate the application of the observational approach for chromium site remediation. A hybrid strategy has been developed to adopt key aspects of the observational approach for site remediation within the context of the complex, carefully-negotiated cleanup program at Hanford.

OBSERVATIONAL APPROACH FOR SITE REMEDIATION

The observational approach is based on principles developed by geotechnical engineers to deal with the uncertainty associated with sub-surface conditions when designing tunnels, dams, and other sub-surface structures. Rather than attempting to completely characterize the sub-surface conditions before beginning construction, the observational method establishes probable conditions and potential, reasonable deviations to those conditions. Contingencies for responding to each deviation are developed and construction is approved if those contingencies can be accommodated by the selected construction techniques. If any of the contingencies cannot be accommodated, however, then additional characterization is required to better define the conditions and reduce the uncertainties.

In the late 1980s the observational approach was proposed as a means of dealing with the inherent uncertainty associated with hazardous waste site remediation, particularly at federal facilities. [1] At the time this proposal was on the edge of generally accepted processes for hazardous waste site remediation. The mainstream approach for selecting remedies at federal facilities was a lengthy and costly process of remedial investigation and feasibility studies. But even after extensive and costly characterization another round of investigation and evaluation could be required to provide the information necessary to prepare a detailed design.

An implicit assumption of that traditional approach was that uncertainties associated with hazardous waste site remediation could be overcome by sufficient investigation and analysis. For waste sites with a single source of contamination, relatively well-defined boundaries to the contamination, and a remedy that had a high probability of successful cleanup, a detailed study/design/remediate approach may have been appropriate – although there is always a significant potential for game-changing uncertainties encountered during the actual cleanup.

Hanford, however, had a far more diverse and complex set of waste sites. The type and extent of contamination at Hanford spanned an incredibly wide range, and for many of the sites relatively little was known about the sources of contamination. Even after years of investigations, the prospects were daunting for conventional characterization of hundreds of waste sites, many of which were known to contain a wide range of radioactive and hazardous materials and mixtures of hazardous and radioactive materials. Conventional characterization of Hanford waste sites was expected to take decades and cost hundreds of millions of dollars. Given the extensive and complex nature of Hanford waste sites, it was likely that even a prolonged and expensive program of conventional remedial investigations and feasibility studies would adequately characterize the sites.

Moreover, the traditional study/design/remediate process did not lend itself to mid-course corrections, particularly at federal facilities that must comply with strict procurement guidelines and regulations. Making changes to the decision documents, designs, and remediation contracts was time consuming and expensive, and expanding the excavation for a waste site to capture more extensive contamination detected during excavation is much easier and more cost effective if the decision is made as soon as the new condition is detected.

These were among the significant challenges faced by DOE cleanup managers as they charted a course for the site cleanup. Adding to these challenges was a strong bias-for-action held by DOE management at Hanford for the overall site cleanup. This bias was consistent with the National Contingency Plan (NCP) and EPA guidance, including specific guidance for remedial project managers that acknowledged the inherent uncertainty associated with hazardous waste cleanups. [2]

The strategy that DOE cleanup managers at Hanford adopted was based on three decision-making paths: 1) Expedited Response Actions, 2) Interim Remedial Measures, and 3) Limited Field Investigations. Their overall strategy called for streamlining the site cleanup investigation and decision process and a bias-for-action acceleration of field remediation. The observational approach was foundational element in DOE's strategy to implement a streamlined process for advancing quickly to actual site cleanups. [3]

Implementation of the observational approach was documented in the Records of Decision and Remedial Design Report/Remedial Action Work Plans issued and prepared for select areas of the

Hanford facility. Specific application of observational approach principles was determined by the project design and field remediation teams.

Key elements of the observational approach applied to site remediation include:

- Establishing remediation goals and objectives, developing a conceptual model, and identifying data gaps
- Selecting and designing the remedial action parameters that could indicate a deviation from expected conditions, and contingency plans for dealing with those deviations
- Implementing the remedial action and monitoring selected parameters
- Responding to deviations with pre-selected contingency plans.

WCH has been successfully employing the observational approach to remediate waste sites, but large chromium-contaminated sites pose significant challenges to the remediation project team.

CHROMIUM SITES AT HANFORD: BACKGROUND AND HISTORY

Sodium dichromate was added to the cooling water in production reactors at Hanford to prevent scaling and fouling of the piping. Although the concentration of sodium dichromate was relatively low, the huge volumes of water required for reactor cooling in turn required large quantities of sodium dichromate, which typically was injected at makeup facilities located near the reactors.

Sodium dichromate contains hexavalent chromium, which is both highly mobile and acutely toxic to fish. Hexavalent contamination moves readily through the soil column, and once it contacts the water table tends to move at the speed of the groundwater flow. If chromium-contaminated groundwater seeps into the nearby Columbia River, fish populations in the river could be jeopardized – particularly the spawning of salmon.

Approximately 2.6 km^2 (1 mi^2) of groundwater is thought to be contaminated with hexavalent chromium near the former D and DR Reactors. An extensive pump-and-treat system has been installed but significant quantities of chromium remain in the soil column and pose a continuing threat to groundwater and the Columbia River. Over the last 15 years, this system has removed over 3,000 kg of hexavalent chromium from the groundwater at the D and H Areas. Moreover, concentrations in groundwater have been generally down for the past 15 years, in some areas by as much as 75%. [4]

Although pump–and-treat operations have been successful at removing significant amounts of chromium from groundwater, the most potent cleanup action is to remove the source term of contaminated material in the soil column. A number of sites at Hanford have been identified as significant source term areas for chromium contamination, and over the last 2 years more than 1 million tons of material has been excavated in an ongoing effort to remove the source of chromium contamination in groundwater.

ISSUES AND CHALLENGES

The highly-mobile nature of hexavalent chromium and the long period of time over which releases occurred led to chromium contamination that is now being cleaned up at several large waste sites. Remediation of these sites is complicated by several key factors, including:

- Chromium site remediation often requires excavating to groundwater – approximately 24 to 27 m (80 to 90 ft) below ground surface. These excavations must be carefully designed and mid-stream changes to the design are very costly.

- There is no uniform agreement about the source, transport, and retention of contamination in the soil. Developing a remediation model that all stakeholders agree on can be difficult.

- The dynamic nature and acknowledged uncertainty of the observational approach can be difficult for stakeholders to adjust to for large and lengthy excavations.

- Incentives for accomplishing schedule milestones can be difficult to establish for waste sites with a high probability of encountering additional, previously unidentified plumes of material during excavation.

Large excavations require careful planning and design to ensure the safety of personnel and to efficiently plan and execute the excavation work. The design for a large chromium site must balance performance and cost, excavating the contamination with "clean" margins no larger than required to ensure the contamination has all been removed. Further complicating matters is the fact that chromium contamination typically follows very narrow channels through soil column discontinuities. An extensive characterization program could easily miss significant pathways and expanded plumes of contamination. Excavation of deep chromium sites must follow the design, but the remediation team must be constantly looking for and ready to respond to indications of contamination that extends beyond the design boundaries.

Design revisions to accommodate new or expanded plumes of contamination are much easier if implemented immediately. A small increase in the size of the final excavation floor requires removing a large amount of clean soil, and expanding the size of an excavation once the design depth has been reached costs much more than if it had been designed and excavated from the outset.

Even more problematic is the late discovery of contamination on the excavation slope after the excavation has been completed. A large effort has to be made to excavate from the top of the excavation to the newly-discovered area of contamination; all of this before any additional remediation can be pursued.

Conceptual Model

A typical conceptual model for a contaminated soil site identifies:

- The probable source or release point of contamination
- The migration pathway(s) the contamination followed from the release
- The nature and extent of the contaminated zone
- A geological profile of the contaminated and layback regions.

The effectiveness of using the observational approach for remediation is determined largely by the extent to which the conceptual model represents the actual conditions and whether the uncertainty of those conditions can be accommodated by the selected remedy (in this case: remove, treat, and dispose). However, developing a good conceptual model of contamination sources and migration pathways for the large chromium sites has proven to be difficult for sites in the 100-D Area.

Potential sources of chromium contamination include leaks and spills from transfer stations, tanks, pipelines, valve boxes, and other related infrastructure. Initial characterization efforts, however, failed to identify specific, high-confidence sources of chromium contamination. At the outset of chromium site cleanup at the 100-D Area, the only condition known with reasonable confidence was the general extent of chromium-contaminated groundwater; the source(s) of that contamination had not been identified. Samples collected from monitoring well installations, investigatory boreholes, and the removal of near-surface infrastructure such as pipelines and valve boxes had not revealed levels of chromium contamination consistent with the high levels observed in groundwater.

The conceptual models for initial site remediation therefore had numerous gaps, and remediation work initially was limited to removing select areas with known contamination. The largest chromium site at the 100-D Area was discovered when stained soil was observed after grading operations at an area adjacent to, but unexpectedly far from, a chromium transfer site.

Regulatory Concurrence

The observational approach was developed by geotechnical engineers for design and construction of dams, deep foundations, runways, and other similar structures. The uncertainties of subsurface conditions at hazardous waste sites have much in common with these standard geotechnical situations, but the regulatory environment is much different. State and federal environmental agencies play a large role in waste site remediation, and they typically have significant influence on the approach and requirements for remediation work. Often, however, regulatory requirements and guidelines impose stringent constraints on the remediation process – constraints that can be in tension or conflict with the flexible nature of the observational approach.

The state of Washington cleanup standards, for example, provide relatively limited flexibility for statistically-based closure. A single sample exceeding cleanup levels can trigger a “hot spot” removal, even if it was within a very high confidence level of being with acceptable limits. A conventional construction project would not hesitate to proceed with that level of confidence, but a site cleanup can be derailed from a single sample that exceeds cleanup levels. Under these circumstances it can be difficult to pre-arrange complete regulator concurrence with the flexible nature of the observational approach.

Client Incentives

Federal agencies are under increasing pressure to show quantifiable results for the large amounts of taxpayer dollars being spent on site cleanups. This pressure, in turn, is channeled through to the contractor by way of specific performance incentives that have explicit pass/fail completion outcomes. These incentives are built into many aspects of project planning and execution, often without provision for variations or modifications that arise from significant variations in contamination or subsurface conditions.

MEETING THE CHALLENGES

The WCH project team is taking a number of steps to meet the challenges faced in implementing an observational approach for remediating large chromium sites. In addition to the standard elements prescribed for any application of the observational approach (e.g., develop a conceptual site model, define potential deviations to expected conditions and contingency plans for meeting them), the project team is following a multi-prong approach to meet the requirements and constraints of remediation work at Hanford. Some of these specific steps include the following.

1. A thin-layer excavation technique is used for removing contaminated material in the intermediate zone between layback and heavily-contaminated material.

2. Regular meetings are held with stakeholders to present the status of and get concurrence with ongoing excavation and in-process sampling.

3. A closeout process has been proposed by WCH to confirm that the sidewalls are below cleanup levels as the excavation progresses.

4. The WCH field remediation team works closely with the CH2M HILL Plateau Remediation Company groundwater team to coordinate the remediation efforts of both prime contractors.

With a design depth of approximately 26 m (85 ft) below ground surface, the excavation of a large chromium site requires extensive layback of material that is below cleanup levels (BCL). A process has been established to document that this layback material is indeed BCL and the excavation of the material is performed at a high production rate, generally with excavation “lifts” of almost 6 m (20 ft). The core volume of contaminated material is expected to be consistent to groundwater, and all of that material is disposed of at the Environmental Restoration Disposal Facility (ERDF), an engineered landfill for Hanford Site cleanups.

One of the significant potential deviations for large chromium sites is a plume of chromium that extends laterally from the known core of contaminated material. Such a plume could lead to another large source of contamination in groundwater, so it is critical that all such plumes be identified. To ensure that no potential plume is missed, the excavation of the intermediate zone between the BCL and the known core of contaminated material is removed in lifts of approximately 1.5 m (5 ft), carefully observing the material as it is excavated for staining, impermeable layers, or other signs of a plume or the potential for one.

Meetings with the key stakeholders ensure that client, regulator, and groundwater team staff and managers are informed about the ongoing status of the remediation and are apprised quickly of any significant changes in anticipated conditions or other deviations. Revisions to the design or planned approach, if necessary, are addressed quickly but are implemented only with concurrence of all stakeholders.

The closeout of a waste site requires verification samples from excavation sidewalls – a process that is typically performed after completion of the excavation. However, walking on the sidewalls of a deep excavation poses a significant safety risk, even with the 2:1 layback WCH requires for the first 12 m (40 ft) of excavation. To minimize the access to the large layback slopes, WCH proposed a modified closeout process under which verification samples are collected as the excavation progresses, thereby ensuring that sampling staff do not have to perform work near the top of a very long slope. An additional benefit to this process is that if there is any detection of contamination from closeout samples, that remediation team has the ability to respond and modify the excavation design earlier, with significant consequent cost savings.

CONCLUSION

Remediation of large, complex waste sites at a federal facility is a daunting effort. Incomplete historical records, multiple stakeholder agencies and staff, federal procurement rules, and contract performance incentives are all potential obstacles to an efficient and cost-effective remediation program; particularly for quick responses to changing conditions. And the deep-excavation required for large chromium sites imposes additional constraints and requirements that must be addressed when implementing a streamlined approach for site remediation.

The observational approach provides a powerful tool for dealing with the inherent uncertainties of site remediation. It offers a structured means of quickly moving into full remediation and responding to the variations and changing conditions inherent in waste site cleanups. But implementing a streamlined, bias-for-action approach to site remediation requires careful planning, good communications, and creative engagement by all stakeholders in the cleanup process.

REFERENCES

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