



Optimization Review Report Operation and Maintenance Optimization Study

**United Chrome Products Superfund Site
Corvallis, Benton County, Oregon
EPA Region 10**

OPTIMIZATION REVIEW

**EPA REGION 10
UNITED CHROME PRODUCTS
CORVALLIS, BENTON COUNTY, OREGON**

FINAL REPORT
July 2019

EXECUTIVE SUMMARY

NATIONAL OPTIMIZATION STRATEGY BACKGROUND

The U.S. Environmental Protection Agency's (EPA's) definition of optimization is as follows:

“Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase. Such actions may also improve the remedy's protectiveness and long-term implementation, which may facilitate progress towards site completion. To identify these opportunities, Regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply some other approaches to identify opportunities for greater efficiency and effectiveness.”¹

An optimization review considers the goals of the remedy, available site data, conceptual site model (CSM), remedy performance, cost-effectiveness, technical improvement, and closure strategy. A strong interest in sustainability has also developed in the private sector and within federal, state, and municipal governments. Consistent with this interest, principles of green remediation and environmental footprint reduction are now routinely considered during optimization reviews, when applicable.

This optimization review includes reviewing site documents, interviewing site stakeholders, visiting the site for one day and compiling a report that includes recommendations intended to improve the following:

- Remedy effectiveness
- Technical improvement
- Cost reduction
- Progress to Site closure
- Environmental footprint reduction

The recommendations are intended to help the site team identify opportunities for improvements in these areas. Analysis of recommendations, beyond that provided in this report, may be needed before implementation of recommendations. All recommendations are based on an independent review and represent the opinions of the optimization review team. The recommendations are not requirements; they are provided for consideration by the EPA Region and other site stakeholders. Also, note that while the recommendations provide some details, they do not replace other, more comprehensive, planning documents such as work plans, sampling plans, and quality assurance project plans (QAPPs).

The national optimization strategy includes a system for tracking the outcome of the recommendations and includes a provision for follow-up technical assistance from the optimization review team as mutually agreed upon by the site management team and EPA Office of Superfund Remediation and Technology Innovation [OSRTI].

¹ EPA, 2012. Memorandum: Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. From: James. E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28.

SITE-SPECIFIC BACKGROUND

The United Chrome Products, Inc. Superfund Site (UCP Site) is a former hard-chrome plating facility that located on approximately eight acres south of Corvallis, Oregon in Benton County, Oregon in EPA Region 10. The Site and nearby property are owned by the City of Corvallis (City).

Electroplating operations began at UCP in 1956 on property leased from the City and continued through 1985. Site investigations began in 1982 and identified chromium (Cr) contamination in soil, groundwater and sediment collected from nearby drainage ditches. The Site is underlain by two water-bearing units. The deeper aquifer is a regional water supply, and at the time of the initial investigation, several private and municipal water supply wells were located downgradient from the Site.

The Site was referred to EPA for hazard ranking in June 1983 and ultimately listed on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) on September 21, 1984. Chrome-plating operations ceased in 1985, and as UCP had no assets, the City of Corvallis was named as the only potentially responsible party (PRP). Site remediation has been conducted as an EPA Fund and PRP-lead project.

EPA conducted a Remedial Investigation (RI) and Feasibility Study (FS) in August 1985. The Record of Decision (ROD) was signed on September 12, 1986. In September 1989, an administrative order issued by EPA required the City to operate a groundwater extraction and treatment system (GETS) in the shallow saturated zone below the facility. EPA entered into a consent decree (CD) with the City in June 1992 which required the operation of the GETS, implementation of soil remedies, engineering and institutional controls (ICs) including a deed restriction on the Site to limit groundwater use and well pumping.

The primary contaminant of concern (COC) at the UCP Site is Cr with the hexavalent oxidation state (Cr VI) presenting the highest human health risk. The current EPA Primary Drinking Water Standard Maximum Contaminant Level (MCL) and remedial goal for total Cr, including trivalent as well as hexavalent oxidation states, is 100 µg/L.

The Site is currently in the long-term operation and maintenance (O&M) phase of remediation. Groundwater extraction in the deep aquifer is ongoing; however, as noted in the fifth Five-Year Review (FYR), the current remedy of groundwater extraction from well DW-8 to maintain hydraulic containment does not appear able to achieve drinking water standards in the near future.

CONCEPTUAL SITE MODEL AND KEY FINDINGS

The UCP facility included a building containing two plating tanks and acid and caustic storage tanks outside of the building. A dry well constructed outside the southwest building corner was used to dispose of floor drippings and product rinsate collected from a sump in the building. The plating tanks extended below the concrete building foundation and were in direct contact with the soil, and leakage from the tanks likely resulted in significant release of Cr (VI) to the subsurface. Additional potential sources included a sludge disposal pit on-Site and drainage ditches where Cr-affected runoff water was collected.

Estimates of the volume of rinsate disposed of in the dry well are about 1,000 gallons per year between 1956 and 1975. According to historical accounts, two large and sudden spills of Cr solutions occurred at the site during the 1979 to 1980-time period. The spills resulted in the release of at least 2,700 kilograms [Kg] (about 6,000 pounds) of Cr over the surface of the site. The initial mass of Cr released to the subsurface was estimated to be 44,470 pounds in 2000. By 2004, an estimated 56,000 pounds of Cr had been extracted via the GETS.

The Site is underlain by unconsolidated deposits of clay, silt, sand and gravel. The upper subsurface

consists of relatively homogeneous, low, permeability silts and clayey silts. An upper, unconfined saturated zone (Upper Aquifer) is present from near ground surface to between 20 to 30 ft bgs. The Upper Aquifer is underlain by a low permeability silt clay stratum ranging in thickness from 5 to 10 ft that functions as an aquitard. The saturated zone below the clay layer, known as the Deep Aquifer, is confined to semi-confined. The media comprising the Deep Aquifer are heterogenous, grading from finer, silty material near the aquitard to sand and gravel at depths up to 45 ft bgs. Groundwater flow in both saturated units is primarily to the northeast, based on historical potentiometric surface maps. The Deep Aquifer is a regional water supply. Municipal water supply wells northeast and downgradient of the Site have been abandoned; however, private water supply wells are present about 4,400 ft northeast of the Site.

The MCL of 100 $\mu\text{g/L}$ total Cr is the remedial goal selected for the Deep Aquifer. The ROD-selected remedial goal in the Upper Aquifer is 10 mg/L (10,000 $\mu\text{g/L}$), 100 times the MCL. The 10 mg/L remedial goal was selected as a concentration protective of the Deep Aquifer based on a contaminant transport equation assuming a 50 $\mu\text{g/L}$ concentration in a hypothetical Deep Aquifer supply well 3,000 ft downgradient of the Site. However, the ROD requires compliance with remedial goals at the plant boundary and the current EPA groundwater policy requires that the MCL be met throughout the Site.

The selected remedy included operation of the GETS in the Upper and Deep Aquifers, an infiltration trench and two infiltration basins to flush Cr from shallow soils, excavation of contaminated soils and modifications to surface drainage as well as ICs.

The Upper Aquifer GETS operated between 1987 and December 2004. The GETS consisted of up to 23 extraction wells and 6 monitoring wells, with chemical pre-treatment ending in 1992 and subsequent direct disposal of extracted groundwater to the publicly owned treatment works (POTW). A combined shallow extraction/infiltration system was operated to limit the vertical gradient between the Upper and Deep Aquifers.

Cr concentrations in the Upper Aquifer fluctuated around 10 mg/L under continued extraction through 2004. Site managers concluded that the Aquifer had attained the cleanup goals in 2003. However, the 95 percent upper confidence limit (UCL) of Cr concentrations at EW-9 was 23.7 mg/L in 2003 (95 percent UCL for EW-15 was 11.7 mg/L and for EW-5 was 11.6 mg/L). The interpretation of 'attainment' at the time was the average Cr concentration at all remaining wells during four quarters of sampling over one year after termination of extraction. Upper Aquifer monitoring and extraction wells were aggressively plugged and abandoned (P&A) between 1996 and 2000, limiting further data availability for interpretation of hydraulic gradients and concentrations. All wells in the Upper Aquifer were plugged by 2007.

Groundwater extraction from the Deep Aquifer began in 1991, and was also terminated for a trial period in December 2004, followed by a one-year quarterly monitoring program. By June 2005, significant increases in Cr were seen at well DW-9, followed by DW-8, DW-2 and DW-15. Concentration rebounds in the Deep Aquifer were ascribed to Cr leaking from the Upper Aquifer. Pumping was resumed at DW-8 in February 2009. Pumping at DW-8 was shut down briefly between September 2009 and January 2010, and a dramatic increase in Cr concentrations was observed at DW-8. Other wells in the network were not sampled during this time frame.

Currently, DW-8 is the only extraction well operating at the Site. The current extraction rate is not reported in recent Site documents. The goal of extraction is to contain the plume in the Deep Aquifer. Extracted groundwater is sent to the POTW for treatment. Cr concentrations in the remaining Deep Aquifer wells are statistically stable. Stable concentrations indicate that contaminant mass continues to enter the network, either from the Upper Aquifer or through desorption from solid matrices, at roughly the rate that groundwater is extracted. Sample results for the downgradient well DW-15 showed an increase in concentration in September 2016. It is unknown if this high value is a result of natural variability or

indicates plume expansion downgradient.

The Site currently has no O&M plan. Cost data for O&M, including Site inspection, monitoring, pumping maintenance and labor costs for DW-8 extraction were not provided for the analysis.

The following data gaps were identified in the CSM:

- The primary source of uncertainty in progress toward Site remedial goals is the quantity and mobility of residual Cr (VI) remaining in the shallow soils, the unconfined Upper Aquifer material and in the clay confining layer.
 - There are two significant sources of uncertainty for the Upper Aquifer. The first is whether the groundwater has actually achieved the stated remedial goal of 10 mg/L throughout the Site. The second is whether the 10 mg/L remedial goal is protective of the Deep Aquifer, preventing downward leaching of Cr (VI) resulting in concentrations above 100 µg/L. No data are available to demonstrate that the Upper Aquifer Cr plume is contained within the property boundaries. The amount and distribution of residual contamination in the Upper Aquifer and its transport pathways to the Deep Aquifer are priority sources of uncertainty in the CSM.
 - The concrete foundation of the former chrome-plating facility is still in place. The amount of mobile Cr remaining under the foundation is unknown. The efficacy of the infiltration/flushing basins and residual Cr concentrations in shallow soils are also unknown.
 - The amount and distribution of residual Cr (VI) trapped in the clay aquitard is unknown. Data from 1990 indicate concentrations of Cr (VI) as high as 4,230 mg/Kg in the clay layer. The original remedy and cleanup goal for the Deep Aquifer are based on the assumption that limited amounts of Cr (VI) are retained in the clay and that the rate of discharge out of the clay matrix is sufficiently low so that concentrations within the Deep Aquifer will stay below 100 µg/L. The current rate of leaching of Cr from the clay aquitard to the Deep Aquifer is uncertain.
- Based on recent data, the groundwater plume in the Deep Aquifer is not delineated. Cr (VI) concentrations at downgradient well DW-15 have risen to over 200 µg/L in 2016, and there is no well farther downgradient to the northeast to delineate the extent of contamination to the 100 µg/L cleanup goal. No sentry wells are present at the edge of the property to demonstrate containment of the plume. As private water supply wells are located about 4,400 ft downgradient from the Site, the lack of monitoring data at the downgradient boundary of the Site is a notable data gap.
- Per- and polyfluoroalkyl substances (PFAS) have been used as fume suppressants in chrome plating operations since 1954, and are a class of emerging contaminants of concern. It is unknown if PFASs were used in chrome-plating operations at the Site.
- Recent pumping data for DW-8 in the Deep Aquifer was not found in Site documents. Overall, detailed pumping data has not been routinely reported since the 2003 FYR. The absence of extraction data limits understanding of plume capture in the Deep Aquifer and the magnitude of discharge of contaminant mass from the upper strata.

RECOMMENDATIONS

Optimization team recommendations for the UCP Site are summarized below.

- ***Reevaluate the remedial goal for the Upper Aquifer:*** Assumptions used to set the remedial goal for the Upper Aquifer at 10 mg/L are incorrect. EPA should clarify both the appropriate remedial goal and where the remedial goal in the Upper Aquifer must be attained (point of compliance [POC]). The remedial goal for the Upper Aquifer should prevent leaching of contamination to the Deep Aquifer in excess of the 100 µg/L MCL throughout the Aquifer.
- ***Monitor the unconfined Upper Aquifer.*** Groundwater in the Upper Aquifer has not been sampled since the monitoring wells were P&A in 2007. Concentrations at the time the wells were plugged were above the 10 mg/L remedial goal. Desorption of Cr (VI) from silty soils in the upper unit have likely caused rebound of dissolved concentrations since termination of the extraction remedy. Four replacement monitoring wells are recommended for plugged wells EW-9, EW-15, EW-6 and EW-29 screened above the clay aquitard. Groundwater elevations at these locations should be used to develop potentiometric surface maps to confirm groundwater flow direction and gradient. At least one additional monitoring well is recommended for the downgradient POC boundary.
 - If sampling results from all new wells are below remedial goals, then wells can be sampled once every five years to coincide with the FYR to demonstrate protective conditions in the Upper Aquifer.
 - If concentrations exceed 100 µg/L in the new wells, then additional wells should be installed to delineate the cross and downgradient plume to below 100 µg/L. Monitoring and potentiometric surface measurements are recommended on a semi-annual basis for two years.
 - Low-flow sampling methods should be considered as a cost-efficient alternative to purging three well volumes.
- ***Sample groundwater for PFAS:*** Sampling for PFAS analytes in the Upper and Deep Aquifers from existing and proposed monitoring wells is recommended
- ***Delineate the plume in the Deep Aquifer:***
 - An additional Deep Aquifer well is recommended for the downgradient POC boundary to demonstrate long-term containment of the plume.
 - As current sampling data indicate a potentially expanding plume in the area of DW-15, at least one new well is recommended to delineate the Cr plume downgradient from DW-15. The area of former well DW-18 is recommended as a potential location based on Site data.
 - If concentrations at DW-18 are above remedial goals, additional wells may be required to delineate the plume to the north, east or south. Additional wells should be located based on interpretation of groundwater potentiometric surface measurements.
 - Low-flow sampling is also recommended for the Deep Aquifer monitoring wells. One round of sampling may be conducted using both low-flow and three-volume purge methods for comparison.
- ***Demolish the remaining concrete building foundation and sample soils:*** The optimization team

recommends demolition of the remaining concrete building foundation and confirmation that soil beneath the pad meets the industrial worker EPC of 170 mg/Kg in the 0 to 3 ft depth interval.

- Conduct soil borings to the top of the water table in areas with staining or in locations adjacent to the former plating tanks under the concrete foundation. Sample soils for total Cr and Cr (VI).
 - If soil below 3 ft bgs is contaminated above the 6,000 mg/Kg soil leaching to groundwater remedial goal, additional soil borings should be extended to the surface of the clay aquitard.
 - If soils below the water table are contaminated above 6,000 mg/Kg Cr, consider additional remedial options such as situ treatment.
 - If shallow, unsaturated soils are the only highly affected medium, an excavation remedy may be considered to remove soils functioning as on-going sources of contamination to the Upper Aquifer.
- **Long-term remedial response:** The current remedial strategy may be stabilizing the migration of Cr in the Deep Aquifer, but it will not restore groundwater in a reasonable time frame. If recommended Site characterization activities in the Upper Aquifer and subsurface soil described above indicate a significant, continuing source of Cr to the Deep Aquifer, the optimization team recommends exploring options for an in-situ reduction remedy for Cr (VI). In situ treatment in the Upper zone would address residual high Cr (VI) concentrations likely remaining below the water table and along the surface of the clay aquitard.
 - **Improved data management and reporting:** PRP consultants should include a complete database of all Site monitoring data, including historical and recent results for all COCs on an annual basis. Annual reports should also include groundwater elevation maps for both the Upper and Deep Aquifers and plume maps for both aquifers with the POC illustrated on the maps. Cross-sections with concentrations shown by well and calculated statistical trends for all remaining wells are also recommended.

CONTENTS

EXECUTIVE SUMMARY	iii
CONTENTS.....	ix
NOTICE AND DISCLAIMER.....	xi
PREFACE.....	xii
LIST OF ACRONYMS AND ABBREVIATIONS.....	xiii
1.0 OBJECTIVES OF THE OPTIMIZATION REVIEW	1
2.0 OPTIMIZATION REVIEW TEAM.....	2
3.0 SITE BACKGROUND.....	3
3.1 Site Description.....	3
3.2 Remedial Action Objectives	5
3.3 Selected Remedy.....	5
4.0 FINDINGS.....	7
4.1 Working Conceptual Site Model.....	7
4.1.1 Primary and Secondary Sources of Contamination	7
4.1.2 Contaminants of Concern.....	7
4.1.3 Geology and Hydrogeology	8
4.1.4 Contaminant Fate and Transport.....	9
4.1.4 Selected Remedy.....	10
4.1.5 Potential Human and Ecological Exposure Pathways	12
4.2 Summary of Data Gaps.....	12
4.2.1 Residual Chromium	12
4.2.3 Delineation of Groundwater Plumes.....	15
4.2.4 Assumptions about Chromium Speciation in RI.....	15
4.2.5 Polyfluorinated Compounds	16
4.2.6 Extraction Data	16
5.0 RECOMMENDATIONS	17
5.1 Reevaluate the Remedial Goal for the Upper Aquifer	17
5.2 Monitor Unconfined Upper Aquifer	17
5.3 Sample Groundwater for PFAS	18
5.4 Deep Aquifer Plume Delineation.....	18
5.5 Demolish Concrete Foundation and Sample Soils.....	19
5.6 Long-Term Remedial Response.....	20
5.7 PRP Data Management and Reporting	21

TABLES

Table 1	Optimization Review Team
Table 2	Other Optimization Review Contributors
Table 3	United Chrome Products Site Chronology
Table 4	United Chrome Site Geology and Hydrogeology
Table 5	Recommendations and Cost Summary

FIGURES

Figure 1	United Chrome Products Superfund Site Map
Figure 2	Cross-Section of UPC Site Stratigraphy
Figure 3	Initial Plume Extent in Upper and Deep Aquifers

APPENDICES

Appendix A	References
Appendix B	Supporting Figures

NOTICE AND DISCLAIMER

Work described herein, including preparation of this report, was performed by HydroGeoLogic, Inc. (HGL) for the U.S. Environmental Protection Agency (EPA) under Task Order 0066 of EPA contract EP-S7-05-05 with HGL. The report was approved for release as an EPA document, following the Agency's administrative and expert review process.

This optimization review is an independent study funded by EPA that evaluates existing data, discusses the conceptual site model (CSM), analyzes remedy performance, and provides suggestions for improving remedy effectiveness, reducing cost, and making progress toward Site closure at the United Chrome Superfund Site (Site). Detailed consideration of EPA policy was not part of the scope of work for this review. This report does not impose legally binding requirements, confer legal rights, impose legal obligations, implement any statutory or regulatory provisions, or change or substitute for any statutory or regulatory provisions. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by EPA.

Recommendations are based on an independent evaluation of existing Site information, represent the technical views of the optimization review team, and are intended to help the Site team identify opportunities for improvements in the current remediation strategy and operation and maintenance (O&M) plan. These recommendations do not constitute requirements for future action; rather, they are provided for consideration by the EPA Region and other Site stakeholders.

While certain recommendations may provide specific details to consider during implementation, these are not meant to supersede other, more comprehensive planning documents such as work plans, sampling plans and Quality Assurance Project Plans (QAPPs), nor are they intended to override Applicable or Relevant and Appropriate Requirements (ARARs) established in the Record of Decision. Further analysis of recommendations, including review of EPA policy, may be needed before implementation.

PREFACE

This report was prepared as part of a national strategy to expand Superfund optimization practices from site assessment to site completion¹ implemented by the U.S. Environmental Protection Agency Office of Land and Emergency Management (OLEM), Office of Superfund Remediation and Technology Innovation [OSRTI]. The project contacts are as follows:

ORGANIZATION	CONTACT	CONTACT INFORMATION
EPA OLEM	Kirby Biggs	EPA OSRTI Technology Innovation and Field Services Division 2777 Crystal Drive Arlington, VA 22202 biggs.kirby@epa.gov Telephone: 703-823-3081
HydroGeoLogic, Inc. (Contractor to EPA)	Doug Sutton Mindy Vanderford	HydroGeoLogic, Inc. dsutton@hgl.com mvanderford@hgl.com

¹ EPA, 2012. Memorandum: Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. From: James. E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28.

LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
ft	feet
lbs	pounds
mg/gal	milligrams per gallon
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
ARAR	Applicable or Relevant and Appropriate Requirement
ARD	EPA Assessment and Remediation Division
bgs	below ground surface
CD	consent decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
Cr	chromium
Cr (III)	trivalent chromium
Cr (VI)	hexavalent chromium
CSM	conceptual site model
E&ES	Easement and Equitable Servitudes
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ESD	Explanation of Significant Difference
FS	Feasibility Study
FYR	Five-Year Review
GETS	groundwater extraction and treatment system
HGL	HydroGeoLogic, Inc.
HQ	EPA Headquarters
IC	institutional control
MCL	Maximum Contaminant Level
NPL	National Priorities List
O&M	operation and maintenance
ODEQ	Oregon Department of Environmental Quality
OLEM	Office of Land and Emergency Management
ORD	Office of Research and Development
OSRTI	Office of Superfund Remediation and Technology Innovation
P&A	plug and abandon
PFAS	polyfluoroalkyl substances
POC	point of compliance
POTW	publicly owned treatment works
PRP	potentially responsible party
QAPP	Quality Assurance Project Plan
RAO	Remedial Action Objective
RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager

R10 Region 10
SOCEM Soil Contamination Evaluation Methodology
UCL upper confidence limit
UCP United Chrome Products

1.0 OBJECTIVES OF THE OPTIMIZATION REVIEW

For more than a decade, the Office of Land and Emergency Management (OLEM) in the Office of Superfund Remediation and Technology Innovation (OSRTI) has provided technical support to the U.S. Environmental Protection Agency (EPA) regional offices by using independent (third party) optimization reviews at Superfund sites. The United Chrome Superfund Site (CERCLIS ID# ORD009043001) (Site) was nominated for an optimization review by the Region 10 (R10) Site Remedial Project Managers (RPMs) and Optimization Coordinators in January 2017. The focus of this optimization review is to evaluate historical data and provide recommendations to optimize the current remedial response, operation and maintenance (O&M), and accelerate progress toward Site closure.

This optimization review used existing environmental data to interpret the conceptual site model (CSM), identify potential data gaps, and recommend improvements to the Site O&M. The optimization review team evaluated the quality of the existing data before using the data for these purposes. The evaluation for data quality included a brief review of data collection and management methods (where practical, the Site Quality Assurance Project Plan (QAPP) is considered), the consistency of the data with other Site data, and the potential use of the data in the optimization review. Data that were of suspect quality were either not used as part of the optimization review or were used with the quality concerns noted. Where appropriate, this report provides recommendations made to improve data quality.

2.0 OPTIMIZATION REVIEW TEAM

The optimization review team, which collaborated with representatives of EPA Headquarters (HQ) and EPA R10, consists of the independent, third-party participants listed in Table 1.

TABLE 1. Optimization Review Team

NAME	ORGANIZATION	TELEPHONE	EMAIL
Doug Sutton ¹	HydroGeoLogic, Inc.	732-233-1161	dsutton@hgl.com
Mindy Vanderford ¹	HydroGeoLogic, Inc.	713-838-7778	mvanderford@hgl.com

¹ Attended the Site meeting on May 25, 2017.

The following individuals contributed to the optimization review process, including attendance at the R10 review meeting or Site visit:

TABLE 2. Other Optimization Review Contributors

NAME	ORGANIZATION	TITLE/ROLE
Jeremy Jennings ¹	EPA R10	Remedial Project Manager
Bernie Zavala ¹	EPA R10	Hydrogeologist
Kira Lynch ¹	EPA ORD	Optimization Coordinator
Jenn Edwards	EPA ARD	HQ Regional Coordinator

Notes:

¹ Attended the Site meeting on May 25, 2017.

ARD = EPA Assessment and Remediation Division

ORD = Office of Research and Development

Documents reviewed for the optimization effort are listed in Appendix A.

3.0 SITE BACKGROUND

3.1 SITE DESCRIPTION

The United Chrome Products, Inc. Superfund Site (UCP Site) is a former hard-chrome plating facility that located on approximately eight acres in the Airport Research Industrial Complex at 2000 Airport Road 3.5 miles south of Corvallis, Oregon in Benton County, Oregon. The Site and nearby property are owned by the City of Corvallis (City). Surrounding land use includes an airport and aviation-related property use and agricultural property. The Site area is illustrated in Figure 1. A chronology of Site activities is presented in Table 3.

Electroplating operations began at UCP in 1956 on property leased from the City and continued through 1985. The Oregon Department of Environmental Quality (ODEQ) initiated Site investigations in 1982. Initial soil concentrations of total chromium (Cr) varied from 200,900 milligrams/kilogram (mg/Kg) at the surface to 29,500 mg/kg 12 to 15 feet (ft) below ground surface (bgs). Groundwater contamination was identified beneath the Site. In addition, surface water and sediment collected from nearby drainage ditches and other locations downstream of the Site showed elevated Cr contamination. The deeper aquifer is a regional water supply. At the time of the initial investigation, several private and municipal water supply wells were located downgradient from the Site.

The Site was referred to EPA for hazard ranking in June 1983 and ultimately listed on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) on September 21, 1984. In January 1985, ODEQ issued a Notice of Assessment of Civil Penalties to UCP for continued violations and for failing to institute operational improvements. The company appealed this order but ceased operating in May 1985. While UCP did not declare bankruptcy, the company had no funds available for remediation. The City of Corvallis was later identified as a potentially responsible party (PRP) (EPA 2017). Remedial actions have been conducted as both PRP and Fund-lead operations, overseen by EPA R10 with support from ODEQ.

EPA conducted a Remedial Investigation (RI) and Feasibility Study (FS) in August 1985. The Record of Decision (ROD) was signed on September 12, 1986. In September 1989, an administrative order issued by EPA required the City to operate a groundwater extraction and treatment system (GETS) in the shallow saturated zone. An Explanation of Significant Difference (ESD) was signed in December 1991 that included the demolition of the UCP building, installation of injection and monitoring wells, and an updated Cr remedial goal. EPA entered into a consent decree (CD) with the City in June 1992 which required the operation of the GETS, implementation of soil remedies, engineering and institutional controls (ICs) including a deed restriction on the Site to limit groundwater use and well pumping.

An additional ESD was issued in August 2010 containing explicit ICs to limit possible exposure at the Site moving forward. It was noted in the ESD that vertical migration of water from the upper zone was a continuing source of contamination in the lower zone. The ESD also required the City to implement an Easement and Equitable Servitudes (E&ES) IC, filed in 2011, that noted the City and/or any successor owners have primary responsibility for maintaining and ensuring that all lessees and tenants are aware of and comply with the IC restrictions until EPA and ODEQ agree to modify or remove the them.

The Site is currently in the long-term operation and maintenance (O&M) phase. Groundwater extraction in the deep aquifer is ongoing; however, as noted in the fifth Five-Year Review (FYR), the current remedy of groundwater extraction from well DW-8 to maintain hydraulic containment does not appear able to achieve drinking water standards in the near future.

TABLE 3. United Chrome Site Chronology

Date	Event
1956	Electroplating activities begin at the Site.
1956-1975	Floor drippings, washings, and product rinsate are disposed via dry well disposal pit
July 1, 1979	Initial discovery of contamination
November 1982	Initial DEQ site investigation for groundwater contamination
June 27, 1983	Hazard Ranking Site (HRS) Assessment and Site Inspection
July 13, 1983	DEQ sends Notice of Violation (NOV) to UCP citing unlawful disposal of hazardous waste and unpermitted discharge of wastes into public waters
July – September 1983	UCP removed sludge from the dry well and placed in drums which were later disposed of at a RCRA-permitted land disposal facility
September 9, 1983	EPA proposed the Site for listing on the NPL
September 21, 1984	EPA listed the Site on the NPL
November 1984	EPA began Site's RI/FS; UCP announces all operations would cease by early 1985
May 1985	UCP equipment and building contents sold at auction. The company did not declare bankruptcy.
August 1985	RI/FS Completed
November 1985	Emergency removal action completed to stabilize the Site after UCP ceased operations
September 26, 1986	EPA Signed ROD selecting remedies
September 24, 1987	EPA initiated remedial action for groundwater
March 1988	Removal and disposal of the plating tanks and residual sludge, decontamination, demolition and disposal of the building, and excavation and disposal of a limited quantity of contaminated soil
June 29, 1988	EPA issued Administrative Order on Consent to City
August 15, 1988	Upper zone groundwater remedial action was initiated
August 11, 1991	Deep aquifer remedial action initiated
December 20, 1991	ESD issued including demolition of the UPC building, installation of injection and monitoring wells, and an updated Cr cleanup standard of 0.1 milligrams per liter (mg/L) or 100 micrograms per liter (100 µg/L).
September 9, 1992	U.S. District Court for Oregon approved entry of a CD between EPA, ODEQ, and the City
November 30, 1992	EPA signed first FYR
December 22, 1993	EPA completed remedial action for groundwater
March 24, 1998	EPA signed second FYR
April 1999	The onsite treatment plant and chemical storage building removed
August 2000	Infiltration basin decommissioned; 17 wells abandoned, including three wells removed during the Soil Removal Project
October 2000	City of Corvallis completed Upper Zone Soil Removal Project, removing 1,956 tons of Cr-contaminated soil
March 31, 2003	EPA signed Third FYR
December 10, 2004	Upper zone and Deep Aquifer extraction wells shutdown
June 2007	Abandoned 21 remaining upper zone extraction and monitoring wells
February 2009	Extraction from Deep Aquifer resumed at DW-8
August 28, 2010	ESD issued containing explicit institutional controls
July 2011	The City excavated soil from six areas within proposed E&S boundary
September 2011	The City completed excavation of 855.3 tons of chromium-contaminated soil from targeted areas of the Site
September 29, 2011	EPA signed Fourth FYR
April 26, 2017	EPA signed Fifth FYR

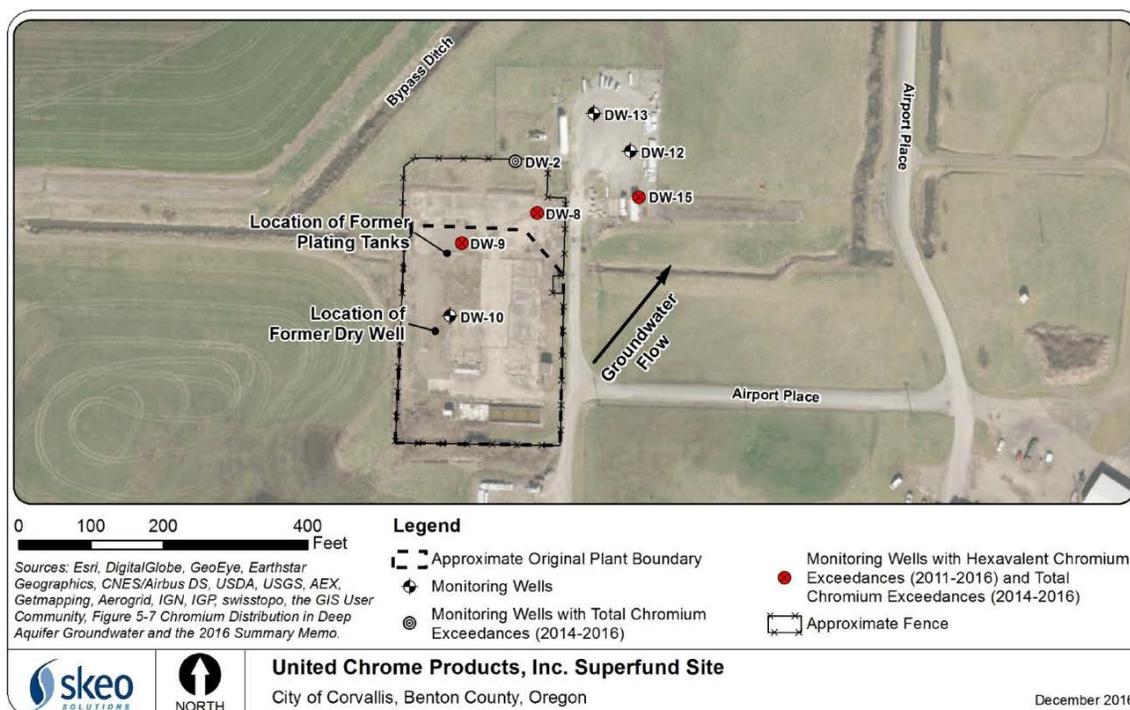


Figure 1: Site Map. [Excerpted from Fifth Five-Year Review (EPA 2017) All figures reproduced in Appendix B.]

3.2 REMEDIAL ACTION OBJECTIVES

Three public health and environmental action objectives were described in the ROD:

- Protection of the public against contact with and ingestion of contaminated groundwater;
- Protection of the environment against the spread of contaminated ground water; and
- Protection of the public against contact with and ingestion of contaminated soil and sediments.

3.3 SELECTED REMEDY

The major components of the selected remedy described in the 1986 ROD included:

- Installation of extraction wells in the upper unconfined groundwater zone (Upper Aquifer);
- Installation of extraction wells in the lower confined, production aquifer (Deep Aquifer);
- Installation of onsite treatment equipment (chemical reduction and precipitation) to remove Cr from extracted groundwater prior to discharge to Muddy Creek or the City of Corvallis publicly-owned treatment works (POTW);

- Construction of two infiltration basins in the areas of the former dry well and plating tanks to flush the contaminated soil above the shallow groundwater table. Approximately 800 tons of contaminated soil were excavated during the construction of the basins.
- Installation of culverts in the adjacent open drainage ditch to isolate the surface drainage system from the inflow of contaminated surface water and groundwater from the Site

In 1982, before listing on the NPL, sludges accumulated in two plating tanks and stored in disposal pits were removed from the Site under the authority of ODEQ. An eight-foot chain link fence was installed around the perimeter of the site, and about 8,000 gallons of spent plating solution, and 11,000 pounds of contaminated soil, along with drums and containers were disposed off-Site during a removal action completed in November 1985 (EPA 2011).

The facility building and plating tanks were demolished in 1988 with off-Site disposal of residual sludge and a small amount of contaminated surface soil. A bypass ditch was constructed to reroute surface water drainage around the Site as part of the selected remedy. Sediment was removed from an on-Site culvert. The concrete foundation of the plating building was left in place.

A network of extraction wells was installed in the Upper and Deep Aquifers with extracted groundwater treated by chemical reduction and precipitation. A total of 49 monitoring and extraction wells were installed in the Upper Zone and 17 wells in the Deep Aquifer. Influent Cr concentrations to the treatment system declined steadily, and the chemical treatment was terminated in 1999 with all extracted groundwater sent to the City POTW for treatment and disposal (EPA 2011).

In December 2004, all pumping at the Site was terminated, and a compliance monitoring program was initiated to determine the effect of the shutdown. Groundwater extraction from the Deep Aquifer was resumed based on evidence of concentration rebound. Extraction from the Upper Aquifer was terminated permanently. In June 2007, the remaining Upper Aquifer extraction and monitoring wells were plugged and abandoned (P&A). Currently, groundwater is extracted from Deep well DW-8 as a containment remedy with groundwater discharged to the POTW.

ICs were implemented in 1993 to prevent Site groundwater use for purposes other than remediation. All property within the 1993 Declaration of Deed Restriction is owned by the City of Corvallis. An additional IC was implemented in 2011, extending controls to surface soil and clarifying the restrictions selected in the ROD.

Further Site characterization in 1998 found two surface locations that warranted an additional removal action of 1,956 tons of Cr-contaminated soil. Additional soil excavation was conducted in 2011 to remove soils outside of the IC zone exceeding risk levels consistent with unlimited use. About 850 tons of soil was excavated and disposed of off-Site. At the time of the excavations, the remedial goal for industrial worker exposure to surface soil was determined to be 170 mg/Kg for total Cr (CH2MHill 2011a).

The 1986 ROD identified the EPA Maximum Contaminant Level (MCL) of 50 µg/L for total Cr as the remedial goal for the Deep Aquifer. The MCL was selected because the Deep Aquifer is in direct contact with groundwater used as a local drinking water supply. The proposed revision to the MCL in 1991 was included in the 1991 ESD. The MCL was increased to 100 µg/L total Cr effective July 1992, and remains in effect.

The 1986 ROD and the 1992 CD identified the point of compliance (POC) for groundwater as the property boundary of the facility. However, based on current EPA policy, the MCL is a relevant and appropriate remedial goal throughout the Deep Aquifer. Therefore, the POC includes the entire lower saturated zone.

4.0 FINDINGS

4.1 WORKING CONCEPTUAL SITE MODEL

The optimization team's working CSM based on investigation efforts to date is presented below.

4.1.1 *Primary and Secondary Sources of Contamination*

Chrome-plating operations began at the Site in 1956. The facility included a building containing two plating tanks and acid and caustic storage tanks outside of the building. A dry well was constructed outside the southwest building corner by removing about 3 ft of native soil and back-filling with sand and gravel. The dry well was completed with a 12-inch diameter, 10-foot long perforated metal pipe. The dry well was used to dispose of floor drippings and product rinsate collected from a sump in the building.

The plating tanks extended below the concrete building foundation and were in direct contact with the soil, and leakage from the tanks likely resulted in significant release of Cr to the subsurface. Cr sludge was placed in a disposal pit on-Site. Drainage ditches where Cr-affected runoff water was collected were in contact with the Upper saturated zone, creating a potential pathway for infiltration of affected surface water.

Estimates of the volume of rinsate disposed of in the dry well are about 1,000 gallons per year between 1956 and 1975. According to historical accounts, two large and sudden spills of Cr solutions occurred at the site during the 1979 to 1980-time period. The spills resulted in the release of at least 2,700 kilograms [Kg] (about 6,000 pounds) of Cr over the surface of the site. Over the next 18 months, at least another 5,400 Kg of Cr was used at the facility (SCS 1991). An estimated initial mass of Cr released to the subsurface of 44,470 pounds was made in 2000. By 2004, an estimated 56,000 pounds of Cr had been extracted via the GETS.

4.1.2 *Contaminants of Concern*

The primary contaminant of concern (COC) remaining at the UCP Site is Cr. At the time of NPL listing, contamination exceeding human health-based risk levels was found in soil, groundwater, sediment and surface water.

The current EPA Primary Drinking Water Standard MCL and remedial goal for total Cr is 100 µg/L. Recently, the protection offered by the 100 µg/L standard has been reviewed based on the differential toxicity of Cr oxidation states and reassessment of the toxicity of Cr via oral ingestion pathways (ATSDR 2012, USEPA 2015).

Cr exists in two principal oxidation states under standard conditions in the environment. Cr (III) is the reduced and most stable form of the element, while Cr (VI) is the oxidized and more reactive form. The two oxidation states display different geochemical, fate and transport properties as well as toxicological effects. Cr (III) is poorly soluble with limited mobility and is poorly reactive, resulting in limited toxicity. Reaction thermodynamics do not favor re-oxidation of Cr (III) to Cr (VI) under most environmental conditions. Conversely, Cr (VI) is highly soluble and mobile in the environment. Cr (VI) can be rapidly reduced under environmental conditions in highly anaerobic sediments. Natural attenuation processes for Cr (VI) in aerobic aquifers are extremely slow.

Cr (VI) is classified as a possible human carcinogen and is responsible for the majority of hazard and excess risk to human and ecological receptors from Cr species (ATSDR 2012). Cr (VI) is known to be hazardous by inhalation, but toxicity by oral ingestion was assumed to be limited as stomach acids were thought to convert Cr (VI) to Cr (III) in the stomach. Recent toxicological data indicate exposure via the oral route may result in increased risk of carcinogenic lesions and that previous assumptions about reduced toxicity due to reduction by stomach acids may have underestimated potential toxicity (ATSDR 2012).

Several regulatory programs have proposed human health-based updates to the federal MCL. The state of California has maintained a state MCL of 50 µg/L since 1977 and has established a public health goal (PHG) of 0.02 µg/L since 2011 (OEHHA 2011). The California Department of Public Health proposed a new state MCL of 10 µg/L in August 2013. The state of New Jersey has considered an MCL for Cr (VI) of 0.7 µg/L. EPA is currently reviewing existing data on Cr (VI) toxicity (USEPA 2015). The June 2015 EPA Regional Screening Level for Cr (VI) in drinking water is 0.035 µg/L. Given the trend of toxicological information about Cr (VI) and ongoing regulatory review of protective concentrations, a reduction in the federal MCL is likely to occur in the future.

The MCL of 100 µg/L total Cr is the remedial goal for the Deep Aquifer. The remedial goal in the Upper Aquifer is 10 mg/L (10,000 µg/L), 100 times the MCL. The 10 mg/L remedial goal was selected in the ROD as a concentration protective of the Deep Aquifer based on a contaminant transport equation assuming a 50 µg/L concentration in a hypothetical Deep Aquifer supply well 3,000 ft downgradient of the Site (Ecology and Environment 1985b).

4.1.3 Geology and Hydrogeology

The Site is underlain by unconsolidated deposits of clay, silt, sand and gravel. The upper subsurface consists of relatively homogeneous, low, permeability silts and clayey silts. An upper, unconfined saturated zone (Upper Aquifer) is present from near ground surface to between 20 to 30 ft bgs. During wet seasons (winter), the water table rises to near ground surface (Ecology and Environment 1985a). The Upper Aquifer is underlain by a low permeability silt clay stratum ranging in thickness from 5 to 10 ft. A cross-section from the FS is reproduced in Figure 2.

Table 4. United Chrome Site Geology and Hydrogeology

Geological Unit	Approximate Depth	Composition
Surface	0 to 3 ft bgs	Pavement and fill, gravel
Upper Aquifer	1 to 20 ft bgs	Clayey silt and silty clay with silty sand lenses
Aquitard	17 to 29 ft bgs	Inorganic clay
Deep Aquifer	29 to 45 ft bgs	Silty sand
	45 to 50 ft bgs	Sandy gravel
Lower Clay Aquitard	Below 50 ft bgs	Stiff clay

The Deep Aquifer is confined to semi-confined. The media comprising the Deep Aquifer are heterogenous, grading from finer, silty material near the aquitard to sand and gravel at depths up to 45 ft bgs. Heterogeneity in the Deep Aquifer may result in variability in concentrations measured at different depths. The Deep Aquifer is a potential water supply and was used historically as a water supply for the City, with private and former municipal wells located downgradient (northeast) from the Site. Private water supply wells draw from the Deep Aquifer. No active water supply wells are currently within 4,000 ft of the Site.

Surface water infiltrates to the Upper Aquifer with excess runoff from the Site draining through ditches along the northern edge of the property into Dry Creek about 1.5 miles east of the Site. The Upper and Lower Aquifers also discharge to Dry Creek. Dry Creek eventually drains to the Willamette River, which is the primary source of drinking water for the City of Corvallis.

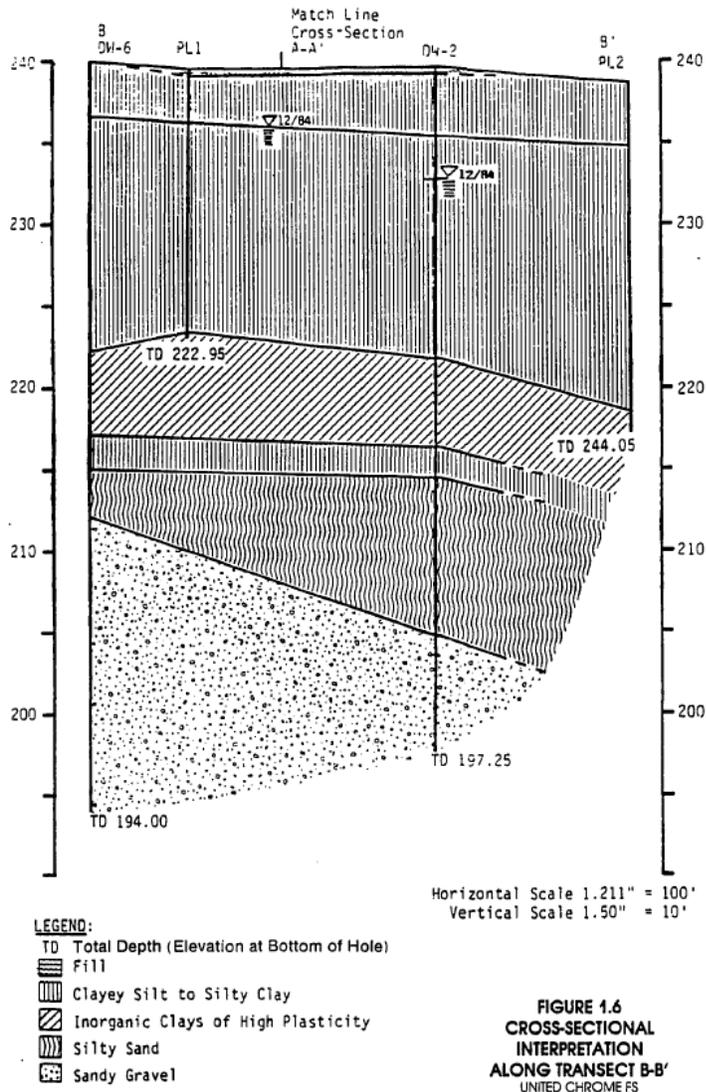


Figure 2: Cross-Section of UCP Site Stratigraphy [Excerpted from FS (Ecology and Environment 1985a) All figures reproduced in Appendix B.]

Groundwater flow is predominantly to the northeast. Horizontal groundwater flow velocities are about 9 ft per year (ft/yr) in the Upper Aquifer and 44 ft/yr in the Deep Aquifer. Vertical groundwater flow from the Upper to the Deep Aquifer occurs at about 11 ft/yr (EPA 2011) due to a relatively high downward hydraulic gradient.

Tests performed during the RI investigation found hydraulic conductivities of 0.61 ft/day to 2.2 ft/day in the unconfined zone. The data indicate the natural hydraulic gradient through the aquitard is downward, with the range of head difference from 0.36 to 4.55 ft (variation is between well pairs and seasonal) (CH2MHill 1990a).

Transmissivities determined for the Deep Aquifer from RI drawdown data ranged from 270 ft²/day to 340 ft²/day. Values of the storage coefficient in the lower aquifer, as determined by the RI pump test data, ranged from 2.1 X 10⁻⁵ to 7.6 x 10⁻⁵. These values are typical for a confined aquifer. Storage coefficients for the unconfined zone and the clay bed could not be explicitly determined during the RI due to the relatively low hydraulic conductivities of these units.

Estimates of the storage coefficient of the clayey silt comprising the upper aquifer ranges from 0.11 to 0.16, and the storage coefficient of the confining clay ranges from 0.03 to 0.10.

The average linear velocity of flow is 0.025 ft/day in the unconfined aquifer, 0.03 ft/day in the clay (where the direction of flow is assumed to be vertical), and 0.12 ft/day in the lower aquifer.

4.1.4 Contaminant Fate and Transport

During initial site investigation in 1983, investigation wells DW-1 and DW-2 were drilled using hollow-

stem auger techniques through the upper contaminated zones into the Deep Aquifer. Initial samples in June 1983 showed background concentrations of Cr at DW-1 and 2.3 mg/L at DW-2. By January 1984, concentrations increased to 19 mg/L at DW-1 and 9.3 mg/L at DW-2. The wells were subsequently removed and appeared to have had insufficient bentonite grout on the casing. (Keely and Boateng 1987) (SCS 1991).

Investigators concluded that the Cr contamination in the Deep Aquifer could be explained by leakage around the well bore holes at the time; however, over the subsequent 30 years, contamination has likely migrated through the aquitard and is slowly diffusing into the Deep Aquifer as indicated by continued high concentrations at wells DW-8 and DW-9.

Some of the assumptions about speciation and mobility of Cr in the RI may not have reflected actual conditions. The RI states that Cr (VI) is not adsorbed to soil, leading to the conclusion that residual Cr (VI) would not be retained in the aquitard below the Upper Aquifer (Ecology and Environment 1985b). This assumption would also suggest that Cr (VI) could be easily flushed from surface soils. While it is true that Cr (III) is more strongly adsorbed, significant amounts of residual Cr (VI) can be retained in low permeability formations with slow release over time.

In addition, early Site documents appear to assume that Cr (VI) will reduce to Cr (III) spontaneously or upon contact with soil organic matter. Subsequent experience at Cr-contaminated sites has refuted this assumption.

4.1.4 Selected Remedy

The following section describes the implementation and operational history of remedies selected in the ROD and modified by the ESDs.

4.1.5.1 Upper Aquifer

The Upper Aquifer GETS operated between 1987 and December 2004. The GETS consisted of up to 23 extraction wells (signified by the "EW" prefix) and 6 monitoring wells, with chemical pre-treatment ending in 1992 and subsequent disposal to the POTW. Pumping regimes were optimized based on changing groundwater concentrations over time, and were also adjusted to account for inflow from the infiltration basins. By 2004, 31.3 million gallons of groundwater had been extracted along with 32,000 pounds (lbs) of Cr (average about 450 milligrams per gallon [mg/gal]).

The combined shallow extraction/infiltration system was operated to limit the vertical gradient between the Upper and Deep Aquifers, minimizing contaminant discharge to the Deep Aquifer. Upper Aquifer monitoring and extraction wells were aggressively P&A between 1996 and 2000, limiting further data availability for interpretation of hydraulic gradients and concentrations.

Based on data collected 1988 through 1997, Upper Aquifer concentrations dropped rapidly after initiation of groundwater extraction, although concentrations exhibited significant variability.

Cr concentrations in the Upper Aquifer fluctuated around 10 mg/L under continued extraction through 2004. Site managers concluded that the Aquifer had attained the cleanup goals in 2003. However, the 95% upper confidence limit (UCL) of Cr concentrations at EW-9 was 23.7 mg/L in 2003 (95% UCL for EW-15 was 11.7 mg/L and for EW-5 was 11.6 mg/L). The decision logic for terminating the active remedy cited in the CD was 'attainment' of the 10 mg/L remedial goal followed by one year of monitoring to confirm concentrations below the goal. The interpretation of 'attainment' at the time was the average Cr concentration at all remaining wells during four quarters of sampling over one year after termination of extraction (CH2MHill 2002).

At the time of termination of the Upper zone extraction system in December 2004, the average influent concentration of extracted groundwater was 10.1 mg/L (Corvallis 2004). During 2004, EW-5, EW-6, EW-9 and EW-15 were active extraction wells. Monitoring wells in the Upper Aquifer showed concentrations below 10 mg/L, but individual extraction wells showed concentrations as high as 25.5 mg/L (Corvallis 2004).

During the compliance monitoring period (December 2004 through September 2005), concentrations at EW-5 increased from 8.8 mg/L to 12.5 mg/L. Concentrations at EW-6 increased from 10.5 mg/L to 11.5 mg/L, with a maximum of 13.8 mg/L observed in March 2005. EW-9 had a maximum concentration of 14.5 mg/L during compliance monitoring period which decreased to 5.2 mg/L at the end of 2005.

In 2004, the region was experiencing a drought with rainfall significantly below the average. Lower overall groundwater elevations in the unconfined unit may have contributed to apparently lower concentrations, influencing the decision to terminate the GETS in the Upper Aquifer. No plume maps or groundwater elevation maps were found for the 2005 through 2007-time frame in documents reviewed.

All remaining Upper Aquifer wells were P&A in 2007. The Fourth FYR asserts that all wells were below the 10 mg/L remedial goal during the shut-down period, but the data do not support this conclusion. Poorly reproduced graphs in the Fourth FYR indicate that concentrations are below 10 mg/L for most wells through 2005, but data for wells EW-5 and EW-6 were above 10 mg/L through 2005.

4.1.5.2 Deep Aquifer

The Deep Aquifer GETS originally had 7 operating extraction wells, two injection wells and 8 monitoring wells, although, over time, the function of each well changed with monitoring wells converted to extraction wells and vice versa. Groundwater extraction began in 1991. Extraction from the Deep Aquifer was also terminated in December 2004, followed by a one-year quarterly monitoring program. By June 2005, significant increases in Cr were seen at DW-9, followed by DW-8, DW-2 and DW-15.

Concentration rebounds in the Deep Aquifer were ascribed to Cr leaking from the Upper Aquifer. Concentration rebound could also result from desorption of entrained Cr from finer-grained material near the top of the Deep Aquifer saturated zone, immediately beneath the clay confining unit. Pumping was resumed at DW-8 in February 2009, whereupon concentrations at DW-2 dropped significantly. Pumping at DW-8 was shut down briefly between September 2009 and January 2010, and a dramatic increase in Cr concentrations was observed at DW-8 (37 ft bgs). Other wells in the network were not sampled during this time frame.

Currently, DW-8 is the only extraction well operating at the Site. The current extraction rate was not found in recent Site documents. The goal of extraction is to contain the plume in the Deep Aquifer. Extracted groundwater is sent to the POTW for treatment. Cr concentrations in the remaining Deep Aquifer wells are statistically stable or show no trend (based on Mann-Kendall analysis of DW-8, DW-9 and DW-15; Appendix B). The largely stable concentrations indicate that contaminant mass continues to enter the network, either from the Upper Aquifer or through desorption from solid matrices, at roughly the rate that groundwater is extracted. Sample results for the downgradient well DW-15 showed an increase in September 2016. It is unknowns if this high value represents variability or indicates plume expansion downgradient (EPA 2017).

4.1.5.3 Shallow Soil

Between August 1988 and September 2000, 17.2 million gallons of potable water was flushed through Upper zone soil using the infiltration basins and the trench. The infiltration trench has not been used since 1993. The total infiltration amount is equivalent to 56 percent of all groundwater pumped from the Upper Aquifer during this time. The infiltration basin remedy was terminated in 2000, prior to excavations to

remove Cr contaminated soil. Additional soil excavation was conducted in 2011 resulting in removal of 855.3 tons (about 600 cubic yards) of surface soil. Excavations were conducted to achieve the 90th percentile exposure point concentration (EPC) to compare with the 170 mg/Kg surface soil remedial action goal (CH2MHill 2011a).

Soil flushing was selected as part of the remedy for surface soils even though the silt/clay soils are relatively poor draining. The FS concluded that soil flushing would be superior to in situ reduction, in part, because the soils were poorly draining. It is noted here that in situ technologies were not as well developed in 1986 as they are currently. Based on data reviewed, the decision to terminate the infiltration basins, and subsequent soil excavations, the soil flushing remedy was not especially effective.

4.1.5.4 Operation and Maintenance

The Site currently has no O&M plan. Cost data for O&M, including site inspection, pumping maintenance and labor costs for DW-8 extraction were not provided for the analysis.

Part of the Site is being leased to CoEnergy as a liquified natural gas tank storage area. During the Site inspection for the 2017 FYR, oil was observed dripping onto the soil around DW-12. The source of the oil was presumed to be an abandoned trailer on Site. Oily residue was seen in the groundwater well.

4.1.5 Potential Human and Ecological Exposure Pathways

The primary exposure pathway of concern at the Site is human direct contact with affected soils and ingestion of groundwater from the Deep Aquifer. There are no complete exposure pathways, currently. The Deep Aquifer is not used as a water supply within 4,000 ft of the Site and ICs limit drilling into both the Upper and the Deep Aquifers. Historical municipal wells in the area have been abandoned. However, private, residential drinking water wells are located about 4,400 ft northeast of the Site along State Highway 99W. The current use of the offsite domestic wells is unknown.

Surface soils in excess of the 170 mg/Kg EPC have been excavated to be protective of industrial workers on Site.

Historically, discharge of Cr-affected material to surface water and sediment was a complete ecological exposure pathway. Surface water discharge has been eliminated and contaminated sediments have been removed from drainage channels, eliminating ecological risk pathways.

4.2 SUMMARY OF DATA GAPS

4.2.1 Residual Chromium

The primary source of uncertainty in progress toward Site remedial goals is the quantity and mobility of residual Cr (VI) remaining in the shallow soils, the unconfined Upper Aquifer material and in the clay confining layer.

4.2.1.1 Upper Aquifer

There are two significant sources of uncertainty for the Upper Aquifer. The first is whether the groundwater has actually achieved the stated remedial goal of 10 mg/L throughout the Site. The second is whether the 10 mg/L remedial goal is protective of the Deep Aquifer, preventing downward leaching of Cr (VI) resulting in concentrations above 100 µg/L.

Current concentrations of Cr (VI) in the Upper Aquifer are unknown. The Upper Aquifer has not been sampled since 2005, and all remaining monitoring wells were P&A in 2007. Data for the time between

shut down of the extraction system in 2004 and September 2005 showed several results above 10 mg/L. Precipitation/recharge during 2004 through 2005 was low, and recovery of groundwater elevations after cessation of extraction in the silty Upper zone is unknown.

Groundwater extraction combined with infiltration likely mobilized water through high hydraulic conductivity zones, with residual contamination remaining in stagnant or low-conductivity zones. The potential long-term rebound of concentrations in the Upper Aquifer after termination of the GETS is unknown. Compliance monitoring data from 2004 to 2005 indicate rebound at wells EW-5 and EW-6, but the compliance monitoring period may not have been long enough to determine the magnitude of rebound, and the monitoring network may not have been extensive enough to fully evaluate the extent. Upper Aquifer concentrations at the edge of the property or IC boundary is unknown. The lack of monitoring data in the Upper Aquifer also limits quantitation of impacts from residual shallow soil contamination.

Based on Site hydrostratigraphy, the silty upper zone soils would retain significant contaminant mass, releasing Cr (VI) slowly over time. Seasonal changes in groundwater elevations, with water rising through contaminated soils could mobilize contamination, causing the variability in groundwater concentrations observed over the monitoring period. As noted above, the decision to terminate extraction was made during a drought where groundwater elevations may have been below significant pockets of soil contamination. In addition, highly contaminated soils remained in place through 2011 when the most recent excavations were performed and may still be in place under the concrete foundation. Contamination below the concrete foundation, if present, could potentially continue to function as an additional source of Cr to the Upper zone after monitoring had ceased.

Potentiometric surface maps of the Upper Aquifer were developed for the RI/FS, but regional pumping at municipal and private supply wells northeast of the Site may have affected flow direction and gradient. Site documents do not provide groundwater potentiometric surface maps during the extraction period. Groundwater elevation maps for the Upper Aquifer between 2004 and 2007 are not available. Current Upper zone groundwater elevations and flow direction are likewise unknown and represent a significant data gap in the Site CSM.

The 1986 ROD remedial goal of 10 mg/L for the Upper Aquifer is based on modeling described in Appendix B of the FS (Ecology and Environment 1985a). The USEPA Soil Contamination Evaluation Methodology [1985 version] (SOCEM – developed by CH2M Hill) was used to estimate the source concentrations protective of a municipal well in the Deep Aquifer 3,000 ft downgradient from the source. The model is a simplified transport equation with assumptions including steady state conditions, constant source, no contaminant retardation or decay, no longitudinal dispersion, no diffusion and no dilution.

Model run assumptions included an estimate of 6.5 mg/L constant concentration in the Deep Aquifer under the Site and that the Upper zone plume would not exceed remedial goals 3,000 ft downgradient from the source. A value of about 20 mg/L in the Upper zone was estimated to be the maximum level that would maintain concentrations at 6.5 mg/L in the Deep Aquifer and prevent concentrations at the downgradient municipal well from exceeding 50 µg/L. The remedial goal was set to 10 mg/L as a ‘conservative’ estimate.

Recent data from the Deep Aquifer (2016) indicate a concentration of 2.48 mg/L Cr (VI) at DW-9 and an order of magnitude lower concentration (0.22 mg/L) at DW-15, about 200 ft downgradient. Current conditions include groundwater extraction from DW-8 (although the rate of extraction is not listed in the 2017 FYR or the 2016 Annual Report). Historically, the Deep Aquifer groundwater plume (> 100 µg/L) was about 400 ft in length by 1990. Concentrations measured in 1990 were 223,000 µg/L at DW-8, 1,230 µg/L at DW-15 and 298 µg/L at DW-18 on a plume line of 250 ft (CH2MHill 1990b). These values show first order dilution pattern (the slope of the natural log versus distance is linear), indicating that the

estimate of 6.5 mg/L would likely be protective of a location 3,000 ft downgradient. However, there is considerable uncertainty about flow gradients, direction and preferential pathways, original time, location and mechanism of release (i.e. migration or cross contamination from well bores). At an estimated seepage velocity of 44 ft/ yr, 3,000 ft is about 70 years travel time for a conservative solute. So, the 6.5 mg/L estimate is likely protective in the short-term given the assumptions about the POC.

However, while the model was developed to assess attainment of the MCL at the municipal well 3000 ft downgradient from the plant, the ROD requires compliance at the plant boundary, and current EPA groundwater policy is to attain the MCL throughout the Site. Either way, the assumption that attaining a Cr concentration of 6.5 mg/L in the Upper Aquifer would result in attainment in the Lower Aquifer is incorrect. In addition, other assumptions about mobility, dilution and dispersion may not reflect the current understanding of the Site. Given this, the remedial goal in the Upper Aquifer should be reevaluated.

The amount and distribution of residual contamination in the Upper Aquifer and its transport pathways to the Deep Aquifer are priority sources of uncertainty in the CSM.

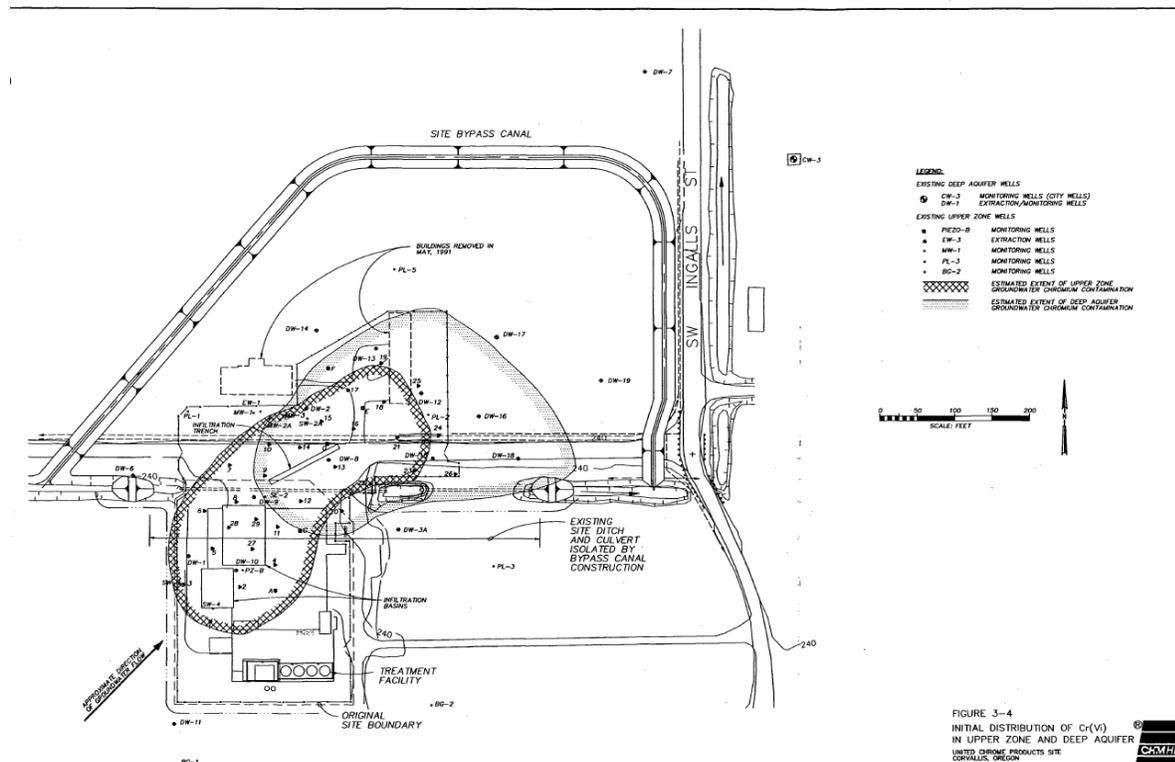


Figure 3: Initial Plume Extent in Upper and Deep Aquifers [Excerpted from 2003 Five-Year Review (EPA, 2003) All figures reproduced in Appendix B.]

4.2.2.1 Shallow Soils

The concrete foundation of the former chrome-plating facility is still in place. Soil borings through the concrete performed in 1985 confirmed contamination under the concrete down to 9 ft bgs, the top of the water table, at the time. Concentrations in soil at 9 ft bgs were 13,400 mg/Kg and in groundwater concentrations were up to 14,600 mg/L. The amount of mobile Cr remaining under the foundation is unknown.

Two infiltration basins were constructed in the area of the dry well and planting tanks to flush Cr to the Upper Aquifer for removal by extraction wells. A 1998 assessment of the efficacy of the infiltration basins found soil in the Upper zone contained up to 23,200 mg/Kg Cr. Either the assumption that Cr (VI) would be easily flushed from surface soil or the original estimate of residual Cr was in error. Subsequent modeling suggested that soil concentrations of 6,000 mg/Kg were sufficient to limit concentrations in the Upper Aquifer to 10 mg/L. In 2000, 1,956 tons of contaminated soil from the upper zone adjacent to the former dry well and planting tanks was removed, and the infiltration basins were decommissioned.

The amount and distribution of residual Cr in subsurface soils is a data gap in the CSM. The long-term effect of leaving affected soils in place, potentially leaching to the Upper Aquifer is also unknown.

4.2.2.3 Clay Aquitard

The 5 to 10 ft of clay comprising the confining layer for the Deep Aquifer has been in contact with contaminated groundwater from the Upper zone for over 30 years. During this time, Cr has likely diffused into the dense clay matrix. Cr (VI) does not adsorb as readily as Cr (III); however, diffusion into fine-grained zones can entrain significant quantities of contamination.

The amount and distribution of residual Cr (VI) trapped in the clay is unknown. Data from 1990 indicate concentrations of Cr (VI) as high as 4,230 mg/Kg in the clay aquitard (DW-9 at 19.5 ft bgs). The original remedy and cleanup goal for the Deep Aquifer are based on the assumption that limited amounts of Cr (VI) are retained in the clay and that the rate of discharge out of the clay matrix will be sufficiently low so that concentrations within the Deep Aquifer will stay below 100 µg/L. Early Site documents also state that Cr will naturally attenuate, with Cr (VI) reducing to Cr (III) under natural conditions.

The current rate of leaching of Cr is uncertain. Cr (VI) sorption/desorption kinetics can be influenced by pH, complexing ions and soil texture.

Historical data indicate that wells drilled through the clay aquitard may have contaminated the Deep Aquifer. Potential continued leaking of contamination through plugged and remaining well bores is also an area of uncertainty.

4.2.3 Delineation of Groundwater Plumes

Based on recent data, the groundwater plume in the Deep Aquifer is not delineated. Cr (VI) concentrations at downgradient well DW-15 have risen to over 200 µg/L in 2016, and there is no well farther downgradient to the northeast to delineate the extent of contamination to the 100 µg/L cleanup goal. The historical high concentration at DW-15 was 1,230 µg/L in 1990. There is also no well to delineate Cr contamination to the south of DW-15, so the lateral distribution of contamination is unknown. Deep Aquifer well DW-9 (38 ft bgs) shows a statistically stable trend for Cr (VI) with a recent concentration of 2,480 µg/L. Well DW-8 at 37 ft bgs showed a concentration of 293 µg/L in 2016, and is on the flow path between DW-9 and DW-15.

The POC for the Upper Aquifer is at the former facility property or the IC boundary. No wells are in place to demonstrate long-term compliance with the remedial goal at these boundaries. As private water supply wells are located about 4,400 ft downgradient from the Site, the lack of monitoring data at the downgradient boundary of the Site is a notable data gap.

4.2.4 Assumptions about Chromium Speciation in RI

As a result of assumptions about Cr speciation and mobility made in the RI/FS, remedies were not selected to manage sorbed Cr (VI) releasing over the long term. The RI considered speciation of Cr

between Cr(III) and Cr (VI), but concluded that the majority of Cr retained in soil and sediments was in the form of Cr (III). The assumption of the remedy design in the FS was “the extraction procedure removes 100 percent of the Cr (VI) associated with soil particles and pore water” (Ecology and Environment 1985a). A key design assumption was that residual Cr in upper zone soils and in the Upper Aquifer would readily flush out to the extraction wells or spontaneously reduce to immobile Cr (III).

The current understanding of chrome-plating waste is that Cr (VI) does not reduce to Cr (III) spontaneously and that significant quantities of Cr (VI) can be retained in low permeability soils. Consequently, assumptions of contaminant attenuation based on spontaneous reduction or efficient flushing have underestimated the efficacy of the selected remedy.

In-situ chemical reduction has been used to successfully remediate Cr (VI) at many former chrome-plating facilities. However, a 2011 opinion from the PRP consultant suggests that in situ reduction is unlikely to remediate residual contamination in the Upper Aquifer as “the chromium mass remaining in the Upper Zone occurs as a solid phase precipitate” (CH2MHill 2011b). The memo goes on to assert that the remaining Cr has low solubility due to its chemical form.

Stable concentrations in the Deep Aquifer under pumping conditions indicates continued mass discharge to the lower unit. The continued mass discharge to the Deep Aquifer indicates the residual Cr is soluble and mobile. Residual Cr (VI) is most likely entrained in the low-permeability upper soils rather than chemically precipitated. The reasons for dismissing in situ treatment as a potentially effective treatment for residual Cr are not supported by the CSM or current understanding of Cr chemistry.

Variations in Upper Aquifer Cr concentrations seen during the RI/FS, and attributed to conversion of Cr (VI) to Cr (III) may have been a result of changing elevation of the water table dropping below highly contaminated zones, only to re-saturate those zones at a later time, resulting in spikes in Cr concentrations.

4.2.5 *Polyfluorinated Compounds*

Per- and polyfluoroalkyl substances (PFAS) have been used as fume suppressants in chrome plating operations since 1954 (EPA 1998). PFAS have also been used in fire-fighting foams that are often used and stored at airports to fight aviation-related fires. PFAS are persistent in the environment and are bioaccumulative. While no MCLs have been established for this class of compounds, the EPA health advisory concentration of PFAs in drinking water is 0.07 µg/L (Federal Register Vol. 81, No.101).

It is unknown if PFASs were used in chrome-plating operations at the Site.

4.2.6 *Extraction Data*

Recent pumping data for DW-8 in the Deep Aquifer was not found in Site documents. Overall, detailed pumping data has not been routinely reported since the 2003 FYR (EPA, 2003). No extraction data were reported in the 2017 FYR. Groundwater extraction data would support understanding of the capture zone for the Deep Aquifer plume, the total amount of mass removed by all remedies and contribute to understanding the contaminant mass discharge from the overlying strata to the Deep Aquifer. Improving the estimates of mass flux from the clay aquitard and the Upper Aquifer would support remedial decisions for restoration of the aquifers. The lack of reported groundwater extraction data is a significant gap.

5.0 RECOMMENDATIONS

Site-specific recommendations are provided for the five major areas associated with optimization: remedy effectiveness, cost reduction, technical improvement, progress toward Site closure, and environmental footprint reduction. Table 5 provides a summary of the recommendations and estimated costs/ savings for implementing each recommendation. The levels of certainty for the cost estimates provided are comparable to those typically prepared for CERCLA FS reports (-30 to +50 percent), and are considered rough estimates for planning purposes.

5.1 REEVALUATE THE REMEDIAL GOAL FOR THE UPPER AQUIFER

Assumptions used to set the remedial goal for the Upper Aquifer at 10 mg/L are incorrect. The understanding of solute transport, EPA policy, Cr geochemistry, and computational models of solute transport have improved dramatically since 1985. For these reasons, the remedial goal for the Upper Aquifer should be reevaluated.

The optimization team recommends either changing the remedial goal in the Upper Aquifer to the MCL (a conservative approach, given the possibility of even lower future regulatory goals for Cr [VI]) or performing new modeling based on updates to the CSM. The new remedial goal should be protective of the entire Deep Aquifer at the MCL (including the area directly below the plating tanks) and prevent off-Site migration of Cr in the Upper Aquifer above the MCL. EPA should clarify precisely where the remedial goal in the Upper Aquifer must be attained.

The optimization team estimates that the modeling effort would cost around \$35,000. The cost of the ESD or ROD amendment to implement or clarify the new remedial goal is not estimated.

5.2 MONITOR UNCONFINED UPPER AQUIFER

As noted above, monitoring wells in the Upper Aquifer were aggressively P&A. As a result, no recent data are available to evaluate Cr concentrations in the Upper Aquifer.

Desorption of Cr (VI) from silty soils in the upper unit have likely caused rebound of dissolved concentrations since termination of the extraction remedy. The optimization team recommends installation of Upper zone monitoring wells near historic high concentrations at former wells EW-9, EW-15, EW-6 and EW-29, and sampling under the current concrete building foundation (see recommendation in Section 5.5). Boring logs from historical wells and historical data should be reviewed in order to place the new well screens near the top of the clay aquitard in areas where maximum residual Cr may be located. The clay aquitard is present at around 20 ft bgs, suggesting that Upper Aquifer samples should be collected between 15 to 20 ft bgs.

Groundwater flow direction and gradient in the Upper Aquifer should be evaluated based on the wells installed near EW-9, EW-15, EW-6 and EW-29 to identify any changes that may have occurred after pumping from extraction and off-Site municipal supply wells was terminated. An additional Upper Aquifer well is recommended for the most downgradient POC boundary, likely in the northeast of the Site.

If sampling results from all new wells are below remedial goals, then wells can be sampled once every five years to coincide with the FYR to demonstrate protective conditions in the Upper Aquifer. However, if concentrations exceed 100 µg/L, then additional wells should be installed to delineate the cross and

downgradient plume to below 100 µg/L.

If sampling results are above the 100 µg/L MCL, monitoring and potentiometric surface measurements are recommended on a semi-annual basis for two years from the new wells. Total Cr and Cr (VI) concentrations as well as physical parameters such as pH, turbidity, and oxidation/reduction potential should be reported. Plume maps and groundwater elevation maps should be included in annual reports from the PRP consultant and summarized in the subsequent FYR. Upper Aquifer wells should be sampled for PFAS compounds (see Section 5.3) as well as Cr species.

It is noted that current groundwater sampling methods in the Deep Aquifer include purging three volumes of well water before sampling. Low-flow sampling techniques may be more time and cost effective, especially if purge water has to be disposed of off-Site. The recommended Upper Aquifer sampling should be conducted using low-flow methods.

Cost for installation and sampling of new wells is estimated to be \$30,000 with annual monitoring costs estimated to be under \$10,000 per year.

5.3 SAMPLE GROUNDWATER FOR PFAS

The 2017 FYR recommends reviewing the facility operating history to determine if PFAS were used for fume suppression at the Site. Fire-fighting foams containing PFAS are often used at airports for aviation-related fire training and for emergency response. The optimization team supports reviewing land use and industrial processes; however, given the time elapsed since termination of industrial operations and the generally poor data management in the intervening years, it is unlikely that a records search would provide definitive evidence of the presence or absence of PFAS.

Direct sampling of the Upper and Deep Aquifers for PFAS from existing or proposed monitoring wells is recommended. Samples should be taken in the area of the former tanks in the Upper and Deep Aquifers. Detection limits for the sampling program should be set below the EPA health advisory of 0.07 µg/L. One sampling event should be sufficient to confirm the absence of PFAS. The cost of one round of sampling is estimated to be \$3,000.

5.4 DEEP AQUIFER PLUME DELINEATION

An additional Deep Aquifer delineation well is recommended along the downgradient northeast POC, in a location similar to that recommended for the Upper Aquifer, to confirm that groundwater migrating off-Site is below the MCL. The POC well can be used to confirm containment of the plume to within the POC boundary, and may be important in demonstrating containment if the Deep Aquifer extraction system is terminated. If the POC well shows concentrations below 10 µg/L, sampling can be conducted once every five years to coincide with protectiveness determinations in the FYR.

If 2017 confirmation sampling in at DW-15 indicates a verified exceedance of the 100 µg/L remedial goal indicating an increasing concentration trend and a potentially expanding plume, another Deep Aquifer monitoring well is recommended to delineate the extent of the plume in the Deep zone. The 2017 FYR states that wells DW-12 and DW-13 are downgradient of DW-15; however, no groundwater elevation maps were provided in the FYR. Historical elevation maps indicate that the native groundwater flow direction in the Deep Aquifer is to the northeast. DW-12 and DW-13 are northwest of DW-15, and therefore, are not directly downgradient from DW-15. The plume appears to have a strong easterly component, based on data from DW-9 to DW-8 to DW-15 and, historically, DW-18. Based on documents reviewed, the plume was never delineated east and south of DW-18.

At least one new well should be placed near the former DW-18 location, screened at a depth of about 40 ft bgs. If total Cr concentrations exceed the 100 µg/L goal at the new DW-18 well, an additional well is

recommended to define the downgradient edge of the plume. Depending on groundwater elevation data and interpreted groundwater flow direction near DW-18, an additional well is recommended near former DW-16 or south of DW-18.

DW-16 was P&A in 1998, showing a final concentration of about 20 µg/L, with a historical maximum of 125 µg/L in 1990. DW-18 had a historical maximum of 298 µg/L, which dropped to the 10 µg/L detection limit by the time it was plugged in 2001, while the Deep Aquifer extractions system was actively pumping. Since 2001, the extraction system has been shut down several times with demonstrated plume migration during each shut-down period, presenting the possibility that the plume has migrated beyond the current monitoring network.

If sample results at the new downgradient well or wells are below 100 µg/L, they can be sampled once every two years to confirm that the plume is contained. If concentrations are above 100 µg/L, the well/wells should be sampled semi-annually for two years to obtain sufficient data to interpret statistical trends.

The sampling frequency of DW-12 and DW-13 can be reduced to biennial (every two years) to delineate the plume to the west. Biennial sampling is recommended as long as concentrations indicate a statistically stable or decreasing trend at these locations.

Annual reports generated by the PRP should include both plume maps and groundwater elevation maps. Data presented in the 2016 Annual report indicate significant variability in depth to groundwater in the confined aquifer over time, but potentiometric surface maps were not generated to illustrate the flow direction and gradient. Effort should be made to identify the source of variability in groundwater elevations and its effect on concentrations and flow regimes and integrate it into the CSM. Additional reporting recommendations are provided in Section 5.7.

Low-flow sampling is recommended for the Deep as well as the Upper Aquifer. The transition to low-flow sampling in the Deep Aquifer may include one sample event where both low-flow and 3-volume purge techniques are used and the sample results compared for consistency.

Aggressive well P&A of monitoring wells is not recommended. The strategy, intended to provide cost efficiency for the PRP, most often results in excessive uncertainty and increased costs.

In addition, an area well survey should be conducted for the Deep Aquifer to identify private water supply wells, and, if possible, their use (domestic or agricultural) and screen interval. For all private supply wells within 5,000 ft of the Site, one round of sampling for total Cr, Cr (VI) and, potentially, PFAS, is recommended.

The cost of the additional Deep Aquifer monitoring wells and sampling is anticipated to be about \$40,000.

5.5 DEMOLISH CONCRETE FOUNDATION AND SAMPLE SOILS

Chrome-plating vats were surrounded by a concrete pad that remains on-Site. Site data indicate that the vats could have leaked or overflowed, resulting in significant contamination below the building foundation. Residual contaminant mass under the concrete building foundation may be an ongoing source of contamination to the Upper Aquifer. It is unknown if contamination below the concrete exceeds the soil cleanup goals.

The optimization team recommends demolition of the remaining concrete building foundation and confirmation that soil beneath the pad meets the industrial worker EPC of 170 mg/Kg in the 0 to 3 ft depth interval.

Conduct soil borings to the top of the water table in areas with staining or in locations adjacent to the former plating tanks. Sample soils for total Cr and Cr (VI). If soil below 3 ft bgs is contaminated above the 6,000 mg/Kg soil leaching to groundwater remedial goal, additional soil borings should be extended to the surface of the clay aquitard. Care should be taken not to extend borings through the clay aquitard to prevent further cross-contamination of the Deep Aquifer.

If soils below the water table are contaminated above 6,000 mg/Kg Cr, consider additional remedial options such as situ treatment (see Section 5.6).

If shallow, unsaturated soils are the only highly affected medium, an excavation remedy may be considered to remove soils functioning as on-going sources of contamination to the Upper Aquifer.

Based on the documents reviewed, calculation of the 170 mg/Kg EPC for human exposure and the 6,000 mg/Kg goal to prevent leaching to groundwater appear reasonable. The appropriateness of the leaching goal can be assessed by evaluating long-term concentration trends in the Upper Aquifer.

The cost of demolition and soil sampling is estimated to be about \$40,000 assuming that the concrete does not need to be disposed of as hazardous waste.

5.6 LONG-TERM REMEDIAL RESPONSE

The current remedial strategy may be stabilizing the migration of Cr in the Deep Aquifer, but it will not restore groundwater in a reasonable time frame.

Concentrations are not decreasing in the Deep Aquifer, and the plume may be expanding. Uncertainty about concentrations in the shallow soil and Upper Aquifer prevent estimations of discharge of Cr to the Deep Aquifer and downgradient areas of the Upper Aquifer. In the absence of more aggressive remedial response, groundwater extraction will continue indefinitely from the Deep Aquifer. As O&M costs for on-going extraction are likely low (estimated < \$25,000 per year), this approach may be cost effective for containment. However, the Site currently has no remedy to restore the drinking water aquifer.

If recommended Site characterization activities in the Upper Aquifer and subsurface soil described above indicate a significant, continuing source of Cr to the Deep Aquifer, the optimization team recommends exploring options for an in-situ reduction remedy for Cr (VI). In situ treatment in the Upper zone would address residual high Cr (VI) concentrations likely remaining below the water table and along the surface of the clay aquitard.

Excavation is likely the most effective and cost-effective remedial option for soils above the water table; however, if there is also contamination below the water table, an in-situ remedy may be able to more effectively address contamination above and below the water table simultaneously. Due to the tight soils and the relatively shallow depth of contamination, in situ chemical reduction coupled with soil mixing would be an appropriate approach. Prior to remediation, the source area would need to be better characterized using the recommendations in the preceding sections coupled with some additional direct push soil sampling to identify the area where the top of the clay is contaminated and where contamination might extend through the clay.

Bench-scale testing with Site soils could be used to evaluate different amendments and appropriate doses. Based on the characterization and bench-scale testing, a field application could be designed. Assuming the area to be treated is approximately 50 ft by 100 ft horizontally and 20 ft deep, the cost of the remediation would likely be approximately \$600,000 for the field contractor, field oversight, confirmation sampling of the treated area, and reporting. Additional cost would be required to monitor the Deep Aquifer over time to confirm decreasing concentrations in Deep Aquifer groundwater. The cost of a full-scale application is highly dependent on the extent of contamination and the outcome of the bench-scale

testing; therefore, the costs should be revisited after this information is available.

The cost of the direct-push characterization is likely \$35,000 for planning, execution, and analysis of three days of direct push soil and groundwater sampling. Part of the cost of this effort may have been covered by recommendations in Section 5.5. The bench-scale testing could be conducted with soils collected from the investigation for approximately \$30,000. Designing, bidding, and planning the remediation field work would likely be an additional \$50,000.

5.7 PRP DATA MANAGEMENT AND REPORTING

Data communication between the PRP and EPA should include a complete database of all Site monitoring data, including historical and recent results for all COCs, on an annual basis. The data should be provided in electronic format (e.g. spreadsheets or databases rather than portable document format [PDF]) to facilitate analysis.

Monitoring reports produced by the PRP consultant and reviewed for this report did not provide complete or well-organized Cr data, or maps with groundwater elevations (not just depth to groundwater) and illustration of the plume extent.

Future annual reports should contain groundwater elevation maps for both the Upper and Deep Aquifers, plume maps for both aquifers with the POC illustrated on the maps. Cross-sections with concentrations shown by well should be included in annual reports. In addition, statistical trends for Cr species should be calculated for all remaining wells in the monitoring network.

Calculated statistical trends can be used to evaluate the efficacy of the selected remedies and the appropriateness of soil leaching to groundwater remedial goals and remedial goals selected for the Upper Aquifer.

PRP reporting improvements are likely to cost less than \$25,000, annually.

TABLE 5. Recommendations and Cost Summary

RECOMMENDATION	EFFECTIVENESS	COST REDUCTION	TECHNICAL IMPROVEMENT	SITE CLOSURE	ENVIRONMENTAL FOOTPRINT REDUCTION	ESTIMATED CAPITAL COST	CHANGE IN ANNUAL COST
<i>5.1 Reevaluate remedial goal for Upper Aquifer</i>	X		X	X		\$35,000	
<i>5.2 Monitor Unconfined Upper Aquifer</i>	X		X	X		\$30,000	\$10,000
<i>5.3 PFAS sampling Upper and Deep Aquifer</i>	X		X			\$3,000	
<i>5.4 Deep Aquifer delineation</i>	X		X	X		\$40,000	\$1,000
<i>5.5 Demolish building foundation and soil testing</i>	X		X	X		\$40,000	
<i>5.6 Planning work for source area treatment</i>	X		X	X		\$115,000	
<i>5.7 Data reporting</i>	X		X	X			\$25,000

“X” Indicates that the recommendation pertains to the indicated optimization category
 Values in parentheses “()” indicate estimated annual cost savings

APPENDIX A:

REFERENCES

- ATSDR. 2012. *Toxicological Profile for Chromium*, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
- CH2MHill. 1990a. *Stage 1 Technical Report United Chrome Products Site Corvallis, Oregon*, CH2M Hill for U.S. Environmental Protection Agency Region 10.
- CH2MHill. 1990b. *Stage 2 Deep Aquifer Drilling Technical Report United Chrome Products Site Corvallis, Oregon*.
- CH2MHill. 2002. *Re-Evaluation of United Chrome Cleanup Goals and Selected Remedy*, CH2M Hill for U.S. Environmental Protection Agency.
- CH2MHill. 2011a. *United Chrome Products Superfund Site - Targeted Soil Removal Remedial Action Completion Report*, CH2M Hill for City of Corvallis.
- CH2MHill. 2011b. *United Chrome Superfund Site 2010 Annual Report*, CH2M Hill for City of Corvallis.
- Corvallis, C. o. 2004. *United Chrome Groundwater Extraction and Pretreatment Facility 2004 Annual Report*, City of Corvallis, Oregon.
- Ecology and Environment, I. 1985a. *Feasibility Study Report United Chrome Products*, Ecology and Environment for City of Corvallis.
- Ecology and Environment, I. 1985b. *Final Remedial Investigation Report United Chrome Products Site*, Ecology and Environment for City of Corvallis.
- EPA. 1998. *Hard Chrome Fume Suppressants and Control Technologies*, U.S. Environmental Protection Agency.
- EPA. 2003. *Third Five-Year Review Report United Chrome Products Site* U.S. Environmental Protection Agency Oregon Operations Office in conjunction with CH2M Hill and USRS Greiner.
- EPA. 2011. *Five-Year Review Report for United Chrome Products (Fourth)*, U.S. Environmental Protection Agency Region 10.
- EPA. 2017. *Fifth Five-year Review Report for United Chrome Products, Inc. Superfund Site, Benton County, Oregon*, U.S. Environmental Protection Agency Region 10.
- Keely, J. F. and K. Boateng. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques — Part 2: Case Histories." *Ground Water* **25**(4): 427-439.
- OEHHA. 2011. *Public Health Goal for Hexavalent Chromium (Cr VI) in Drinking Water*, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

SCS. 1991. *Issue Paper: Contamination of Deep Aquifer at United Chrome Products Site*, SCS Engineers for the City of Corvallis.

USEPA. (2015). "Integrated Risk Information System: toxicological Review of Hexavalent Chromium (2010 External Review Draft)." Retrieved September 2015, 2015, from http://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=221433.