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Technology Screening Memo

To	Katie Daugherty, R.G., Oregon DEQ
From	Todd Slater, LSS David Weymann, PE Brendan Robinson, PE
Date	15 February 2023
Reference	Arkema Facility. ECSI No. 398
Subject	Feasibility Study – Technology Screening Memo

1. INTRODUCTION

Legacy Site Services LLC (LSS) is conducting a feasibility study (FS) to assess remedial alternatives at the former Arkema facility in Portland, Oregon (the facility). The *Feasibility Study Work Plan* (FSWP) identified the contaminants of concern and the process to assess remedial alternatives for soil and water. The Oregon Department of Environmental Quality (DEQ) accepted the revised FSWP, as modified by DEQ's 16 January 2019 letter. ERM submitted the compiled final FSWP on behalf of LSS on 12 January 2022 (ERM 2022). The FSWP does not identify technologies and alternatives to be considered in the FS.

The *Preliminary Hot Spot Evaluation* (HSE) identified hot spots in soil and water. Oregon's environmental cleanup law requires that remedies treat or excavate hot spots of contamination to the extent feasible (Oregon Hot Spot Rule [DEQ 1998]; ORS 465.315, OAR 340-122-0090). The DEQ's 21 June 2021 letter accepted the 14 April 2021 revised preliminary HSE, subject to minor comments to be addressed in the FS.

DEQ, LSS, and ERM-West, Inc. (ERM) have discussed and agreed to a stepwise approach to completing the FS. Two interim deliverables will help frame the process and details of the FS, followed by the FS report itself.

1.1 Functional Unit Delineation Memo

The *Functional Unit Delineation Memo*, submitted 23 November 2022, identified areas of the site that reflect sources, pathways, and risk drivers to facilitate screening and selection of remedial technologies.

In the context of the Arkema FS, a Functional Unit (FU) is a concept to help segregate areas of the site to select remedial alternatives. The *Functional Unit Delineation Memo* identified the FUs that will be used in combination with technology screening to evaluate alternatives in the FS. The DEQ's 27 December 2022 letter accepted the 23 November 2022 revised *Functional Unit Delineation Memo*.

1.2 Technology Screening Memo

The FSWP transmitted to the DEQ on 12 January 2022 outlined the basis and approach to the FS, but it did not identify technologies or alternatives to be evaluated in the FS. The *Technology Screening Memo* (this document) proposes technologies to be evaluated in the FS. The *Technology Screening Memo* identifies treatment technologies and conducts the preliminary screening for assembling technologies into alternatives in the FS, as applicable to the agreed functional units.

The following are objectives of the *Technology Screening Memo*:

- Refine the approach of the FS
- Screen and identify technologies to be carried forward and evaluated further in the FS
- Identify technologies that will not be carried forward in the FS

This *Technology Screening Memo* incorporates the following:

- Remedial alternatives objectives (RAOs) of the upland remedy (FSWP Section 5.3).
- Performance of the groundwater extraction and treatment system (GWET) and assumptions regarding the GWET as a technology in the FS to achieve source control. The *Functional Unit Memo* and this *Technology Screening Memo* will assume that the modified GWET will meet performance objectives.

The content of this *Technology Screening Memo* will be included in the FS. The FS will assess protectiveness and balancing factors in more detail (e.g., detailed costing) of the technology alternatives recommended in this *Technology Screening Memo*.

After LSS and DEQ agree to the recommendations in the interim steps, the FS will be completed as outlined in the FSWP. The FS will follow DEQ guidance, incorporate mutually agreeable requests, and recommend remedial action technologies and alternatives.

2. REMEDIAL ACTION OBJECTIVES

As discussed in the 12 January 2022 FSWP, the site-specific RAOs include:

- RAO 1 – Reduce upland human health risks to acceptable risk-based levels from incidental ingestion, inhalation, and direct contact with soil under trespasser, outdoor worker, and outdoor worker after redevelopment and construction worker scenarios.
- RAO 2 – Reduce riverbank terrestrial ecological risks to acceptable risk-based levels from ingestion and direct contact with soil.
- RAO 3 – Prevent or reduce the potential for migration of constituents of concern (COCs) in surface soil and riverbank soil to accumulate in Willamette River sediment above acceptable risk-based levels.
- RAO 4 – Treat or remove soil hot spots to the extent feasible based on remedy selection factors.

- RAO 5 – Prevent or reduce the migration of groundwater COCs to the Willamette River above acceptable risk-based levels for surface water receptors.
- RAO 6 – Treat or remove groundwater hot spots to the extent feasible based on remedy selection balancing factors.
- RAO 7 – Reduce the potential for dense nonaqueous-phase liquid (DNAPL) to act as a continuing source for COCs in groundwater.
- RAO 8 – Treat or remove DNAPL hot spots to the extent feasible based on remedy selection balancing factors.
- RAO 9 – Reduce the migration of COCs in stormwater to the Willamette River that are at or above acceptable risk-based concentrations for surface water receptors.
- RAO 10 – Reduce the migration of COCs in stormwater to the Willamette River to prevent accumulation of COCs in river sediment above risk-based levels.

These RAOs were created under the assumption that only remedies that are technically practicable, appropriate, and feasible will be selected in the FS.

3. TECHNOLOGY SCREENING PROCESS

This section describes certain assumptions and conditions that are fundamental to the technology screening.

3.1 Exposure Point Concentrations

The FS assumes that concentrations of COCs in groundwater are transported unattenuated to porewater in the Willamette River. Revisions to this concept will occur as part of the Remedial Design.

3.2 Screening of Candidate Technologies

Candidate technologies were identified and screened using the following sequence and tools:

1. Identified applicable technologies from United States Environmental Protection Agency's (USEPA) CLU-In database by COC and environmental media.
2. Evaluated technologies under each balancing factor based on:
   a. Hydrogeologic conceptual site model (HCSM).
   b. Interim actions and ongoing remediation at the site and the effectiveness and applicability of those actions for additional remediation.
   c. Analysis of similar technologies for similar sites.
   d. The LSS project team's professional experience.

The tables in the memo summarize the results of the initial screening process.

4. TECHNOLOGIES BY FUNCTIONAL UNITS

The *Functional Unit Delineation Memo* described the proposed FUs. This section describes each FU, provides a brief description of potentially feasible options, and screens out alternatives that do not meet the Remedial Action Objectives. The goal for this section is to provide a comprehensive list of FUs, along with their initially feasible technologies.

Table 1 lists and describes the FUs, the COCs, and the risk pathways. Table 2 evaluates potential technologies based on Remedy Selection Balancing Factors and comments on the justification for numeric ratings. Table 3 summarizes the proposed candidate technologies for each FU.

4.1 FU #1 – Riverbank

FU-1 consists of the top 3 feet of soil along the riverbank from the fence line on the east sides of Lots 1 through 4 from the top of the bank to the river (mean high water approximately 12 feet NAVD88). The riverbank has concentrations of metals and pesticides in soil that exceed criteria for direct and leaching to groundwater (LtGW) exposure pathways, and for volatile organic compounds (VOCs) in soil for the LtGW pathway.

Candidate technologies for FU-1 include excavation and capping from the top of the bank to the river (mean high water approximately 12 feet NAVD88). Applicable remedial action objectives include RAOs 1, 2, 3, and 4.

As part of the in-water remedy under the River Mile 7 West Project Area Remedial Design Administrative Settlement Agreement and Order on Consent (ASAOC) (USEPA 2020), the upland FS will not consider FU-1.

4.2 FU #2 – Soil in all Lots (not including Acid Plant Area)

FU-2 consists of soil in all Lots to a depth of 15 feet on Lots 1 through 4 (excluding the Acid Plant Area consisting of FU-3 and FU-4). Soil in FU-2 has concentrations of metals and pesticides in soil that exceed criteria for direct exposure and LtGW pathways.

Candidate technologies for FU-2 include institutional controls, excavation, capping, in situ phytoremediation, in situ chemical oxidation (ISCO and in situ chemical reduction (ISCR). ISCO and ISCR could potentially be used in combination with in situ chemical stabilization (ISCS) or in situ soil solidification (ISSS).

4.3 FU #3 – Soil in Acid Plant Vicinity

FU-3 consists of soil in an area surrounding and downgradient of the Acid Plant Area. FU-3 has similar contaminants as FU-2 (metals and pesticides), but also has VOCs detected in soil and overlies the area where DNAPL has been observed in groundwater.

Candidate technologies for FU-3 include institutional controls, excavation, capping, in situ soil flushing, thermal treatment, soil vapor extraction (SVE), ISCO, and ISCR. As with FU-2, ISCO and ISCR could potentially be used with ISCS or ISSS.

4.4 FU #4 – Soil in Acid Plant Area

FU-4 includes the soil in the Acid Plant Area. Soil in FU-4 has metals and pesticides at concentrations that exceed criteria for both direct exposure and LtGW pathways, VOCs in soil that exceed LtGW criteria, has observed DNAPL in soil, and overlies an area where DNAPL has been observed in groundwater.

Candidate technologies for FU-4 are the same as in FU-3. However, the ratings in Table 2 differ from one another since the application of the candidate technologies will likely be influenced by the concentrations present, the presence of DNAPL in the soil, and the chosen treatment technologies for the underlying groundwater FUs.

4.5 FU #5 – Shallow and Intermediate Groundwater in Lots 1 and 2

FU-5 includes shallow and intermediate groundwater in Lots 1 and 2. FU-5 consists of VOCs in shallow and intermediate groundwater in Lots 1 and 2 as well as metals, dioxins, furans and dissolved VOCs in groundwater in all zones, and apparent dissolved pesticides in the shallow zone. VOCs and some metals and pesticides in FU-5 are a trespass plume from an upgradient source.

Candidate technologies for FU-5 include institutional controls, monitored natural attenuation, permeable reactive barrier or barriers, thermal treatment, ISCO or ISCR potentially combined with either ISCS or ISSS, enhanced aerobic/anaerobic biodegradation, and hydraulic control. In the context of the FS, hydraulic control is only an engineering control in all FUs.

4.6 FU #6 – Shallow and Intermediate Groundwater in the Riverside Portion of Lot 3 not Bound by the Groundwater Barrier Wall

FU-6 includes shallow and intermediate groundwater in the riverside portion of Lot 3 not bound by the Groundwater Barrier Wall (GWBW). FU-6 consists of chlorinated VOCs and pesticides in shallow groundwater and chloride and metals in shallow and intermediate groundwater.

Candidate technologies for FU-6 include institutional controls, monitored natural attenuation, permeable reactive barriers (e.g., granular activated carbon), thermal treatment, ISCO or ISCR potentially combined with either ISCS or ISSS, enhanced aerobic/anaerobic biodegradation, and hydraulic control.

As with FU-3 and FU-4, the candidate technologies for FU-5 and FU-6 are similar, but application of the treatment technologies in each of the FUs may differ due to COC concentrations present and site conditions. FU-6 is physically underneath the GWET plant, part of the site stormwater system, and is north of the barrier wall.

4.7 FU #7 – Shallow, Intermediate, and Deep Groundwater in Uplands Portion of Lots 3 and 4

FU-7 includes shallow, intermediate, and deep groundwater in uplands portion of Lots 3 and 4. FU-7 consists of metals, pesticides, dioxins, and furans in shallow, intermediate, and deep groundwater, and chloride in shallow and intermediate groundwater. Per the HSE, the source of dieldrin in FU-7 is uncertain, possibly indicating an offsite source.

Candidate technologies in FU-7 include institutional controls, monitored natural attenuation, permeable reactive barrier or barriers, ISCO or ISCR potentially combined with either ISCS or ISSS, enhanced aerobic/anaerobic biodegradation, and hydraulic control.

4.8 FU #8 – Shallow, Intermediate, and Deep Groundwater in Northern Riverside Portion of Lots 3 and 4 not Bound by the Groundwater Barrier Wall

FU-8 includes shallow, intermediate, and deep groundwater in northern riverside portion of Lots 3 and 4 bound by the GWBW. FU-8 consists of metals, chloride, VOCs, and pesticides in the shallow, intermediate, and deep zones and furans in the shallow zone. Per the HSE, the source of beta BHC/HCH and heptachlor in groundwater is uncertain, possibly indicating an offsite source.

Candidate technologies for FU-8 include institutional controls, monitored natural attenuation, ISCO or ISCR potentially combined with either ISCS or ISSS, thermal treatment, hydraulic control, and enhanced aerobic/anaerobic biodegradation.

4.9 FU #9 – Shallow, Intermediate, and Deep Groundwater in Acid Plant Area

FU-9 includes shallow, intermediate, and deep groundwater in the Acid Plant Area. FU-9 consists of metals, chloride, VOCs, and pesticides in the shallow, intermediate, and deep zones and furans and DNAPL in the shallow zone. Per the HSE, the source of heptachlor and endosulfan in groundwater is uncertain, possibly indicating an offsite source.

Candidate technologies for FU-9 are the same as FU-8. However, application of the treatment technologies in both functional units may differ due to COC concentrations present, site features, and the presence of DNAPL.

4.10 FU #10 – Shallow, Intermediate, and Deep Groundwater on Southern Riverside Portion of Lot 4 Bound by the Groundwater Barrier Wall

FU-10 includes shallow, intermediate, and deep groundwater on southern riverside portion of Lot 4 bound by the GWBW. FU-10 consists of metals, chloride, perchlorate, pesticides, and VOCs in the shallow, intermediate, and deep zones. Candidate technologies include institutional controls, monitored natural attenuation, ISCR or ISCO potentially combined with either ISCS or ISSS, enhanced aerobic/anaerobic biodegradation, and hydraulic control.

4.11 FU #11 – Gravel/Basalt Zone Groundwater on Lots 3 and 4

FU-11 includes gravel/basalt zone groundwater in Lots 3 and 4. FU-11 consists of metals, chloride, VOCs, pesticides, and furans in gravel/basalt zone groundwater. Candidate technologies include monitored natural attenuation, ISCO or ISCR potentially combined with either ISCS or ISSS, enhanced aerobic/anaerobic biodegradation, and institutional controls.

4.12 FU #12 – Deep and Gravel/Basalt Zone Groundwater on Lots 1 and 2

FU-12 includes deep and gravel/basalt zone groundwater in Lots 1 and 2. FU-12 consists of metals, chloride, VOCs, pesticides, furans, and dioxins in the deep and gravel/basalt groundwater zones. Similarly to FU-5, the VOCs in this FU are a trespass plume from an upgradient site.

Candidate technologies include monitored natural attenuation, ISCO or ISCR potentially combined with either ISCS or ISSS, enhanced aerobic/anaerobic biodegradation, and a permeable reactive barrier.

5. NEXT STEPS

Preparation of the FS is ongoing. After the DEQ reviews and approves this memo, the FS will develop details of the retained technologies.

6. REFERENCES

ERM-West, Inc. (ERM). 2005. *Upland Remedial Investigation Report Lots 3 & 4 and Tract A – Revision 1*. December.

ERM. 2009. 2009 *Response to Public Comments on the Groundwater Source Control Measure Interim Remedial Measure Focused Feasibility Study Arkema Inc. Facility, Portland, Oregon*. April 2009.

Integral. 2008. *Human Health Risk Assessment, Arkema Site: Upland Areas*. 5 December.

Integral. 2009. *Arkema Upland Level II Screening Ecological Risk Assessment*. 16 January.

Table 1: Functional Units
***Former* Arkema Facility, Portland, Oregon**
Feasibility Study Technology Screening Memo

Functional Unit		Figure	Historical Operations and Sources of Contamination	COCs (1)	Exposure Pathways	Media, Depth, Hydro-Units	Description (2)
1	Soil Riverbank (addressed under in-water FS)	1	Historic operations listed in table 1 are considered sources of contamination	Metals, pesticides, VOCs, dioxins, and furans	▪ Human: site workers (depth up to 3 feet), trespasser (surface) ▪ Ecological: direct exposure, LtGW ▪ Riverbank erosion	• Shallow soil • 0 – 3 feet (Direct exposure) • Riverbank, site wide	The riverbank soil has been affected by at least one COC, as delineated in the FSWP and HSE. See FSWP Figure 2-2. Previous negotiations (DEQ 2017) with the DEQ identified soil removal to a depth of 3 feet as the presumed remedy. Soil disposal in accordance with criteria established in the FS and in the RD/RA. This is part of the in-water remedy in accordance with ASAOC for River Mile 7 West.
2	Soil Lots 1, 2, 3, & 4 (not including acid plant area)	1	Historic operations: Chlorate plant, old caustic tank farm, stormwater drain system, former cell repair room	Metals and pesticides - LtGW,	▪ Ecological: LtGW ▪ Human: site workers pesticides (depth up to 15 feet), trespasser arsenic Lot 1 (depth up to 3 feet)	• Soil • 0 – 15 feet	Composite hot spots of pesticides and metals with both potential LtGW and direct exposure.
3	Soil Acid Plant Vicinity (not including DNAPL zone)	1	Historic operations: Acid Plant Area and sub areas	Metals, pesticides, and VOCs in soil	▪ Human: site workers (depth up to 15 feet), trespasser (surface) Ecological: LtGW	• Soil • 0 – 15 feet	Historical releases of VOCs and composite hot spots of metals and pesticides potential LtGW. Area surrounding the former site of the acid plant.
4	Soil Acid Plant	1	Historic operations: Acid Plant Area and sub areas	Metals, pesticides, VOCs, and DNAPL in soil -	▪ Human: site workers (depth up to 15 feet), trespasser (surface) Ecological: LtGW	• Soil • 0 – 15 feet	Historical releases of VOCs, DNAPL (chlorobenzene), and composite hot spots of metals and pesticides, potential LtGW.
5	Shallow and Intermediate Groundwater Lots 1 & 2	2	Historic operations: BPA Substation Annex	Metals, pesticides, dioxins, furans, VOCs, and chloride in shallow and intermediate zones.	▪ Ecological: Groundwater to surface water.	• Groundwater • Shallow and intermediate • Lots 1 & 2	Metals, pesticides, dioxins, furans, and chloride in groundwater in shallow and intermediate zone. VOCs in the shallow and intermediate zones. GW in the deep and gravel/basalt zones are a part of FU-12.
6	Groundwater Riverside of Lot 3	2	Historic operations: Cell liquor storage	VOCs and pesticides in shallow groundwater, chloride, and metals in shallow and intermediate groundwater	▪ Ecological: Groundwater to surface water	• Groundwater • Shallow, intermediate, and deep • Riverside Lot 3	Riverside portion of Lot 3 not bound by the groundwater barrier wall (GWBW). VOCs and pesticides in shallow groundwater and metals and chloride in shallow and intermediate zones.
7	Groundwater Lots 3 & 4	2	Historic operations: Cell repair room, BPA main substation, chlorate process	Metals, furans, and pesticides in shallow intermediate, and deep groundwater and chloride in shallow and intermediate groundwater	▪ Ecological: Groundwater to surface water	• Groundwater • Shallow and intermediate • Lots 3 & 4	Shallow and intermediate groundwater with metals, pesticides, and chloride.
8	Groundwater Northern Portion of Site Partially Bound by GWBW	2	Historic operations: Old caustic tank farm, chlorine finishing	Metals, chloride, pesticides, and VOCs in shallow, intermediate, and deep groundwater, and dioxins and furans in the shallow zone	▪ Ecological: Groundwater to surface water	• Groundwater • Shallow, intermediate, and deep • Lots 3 & 4	Northern portion of the site in Lots 3 and 4 that is partially bound by the GWBW. Metals, chloride, pesticides, and VOCs in shallow, intermediate, and deep groundwater. Dioxins and furans in the shallow zone.

Table1: Functional Units
***Former* Arkema Facility, Portland, Oregon**
Feasibility Study Technology Screening Memo

Functional Unit		Figure	Historical Operations and Sources of Contamination	COCs (1)	Exposure Pathways	Media, Depth, Hydro-Units	Description (2)
9	Groundwater in DNAPL Plume Area	2	Historic operations: Acid Plant Area	Metals, chloride, pesticides, and VOCs in shallow, intermediate, and deep groundwater. Furans and MCB DNAPL in shallow groundwater.	▪ Ecological: Groundwater to surface water	• Groundwater • Shallow, intermediate, and deep • Lots 3 & 4	Northern portion of the site in Lots 3 and 4 that is partially bound by the GWBW. Metals, chloride, pesticides, and VOCs in shallow, intermediate, and deep groundwater. Includes dioxins and chlorobenzene DNAPL underneath the acid plant area.
10	Groundwater Southern Portion of Site Partially Bound by GWBW	2	Historic operations: Chlorate cell room, salt pads, sub-stations	Metals, chloride, pesticides, VOCs, and perchlorate in shallow, intermediate, and deep groundwater	Ecological: Groundwater to surface water	• Groundwater • Shallow, intermediate, and deep • Lot 4	Southern portion of the site that is partially bound by the GWBW. Metals, chloride, pesticides, VOCs, and perchlorate in shallow, intermediate, and deep groundwater.
11	Gravel/Basalt Groundwater Zone on the Lots 3 & 4	2	Historic operations listed in the FU Memo are considered sources of contamination	Metals, chloride, pesticides, furans, and VOCs	Ecological: Groundwater to surface water	• Groundwater • Gravel/Basalt Zone • Lots 3 & 4	Gravel/basalt zone on southern portion of the site with metals, chloride, pesticides, furans, and VOCs.
12	Groundwater Deep and Gravel/Basalt Groundwater Zone on the Lots 1 & 2	2	Historic operations: Rhone-Poulenc (VOCs)	Metals, chloride, pesticides, dioxins, furans and VOCs	Ecological: Groundwater to surface water	• Groundwater • Deep zone groundwater • Gravel/Basalt Zone • Lots 1 & 2	Gravel/basalt zone on northern portion of the site with metals, chloride, pesticides, dioxins, and VOCs. VOCs in Lots 1 and 2 represent a trespasser plume.

Notes:
LtGW = leaching to groundwater

(1) = COCs listed in table are those that exceed hot spot thresholds
(2) = Also see text description

Table 2: Technology Screeening Table
***Former* Arkema Facility, Portland, Oregon**
Feasibility Study Technology Screening Memo

Contaminant of Concern - COCs	Technology	Preliminary Remedy Selection Balancing Factors (Rated 1-5)(1)					Comments	Retained Yes/No
		Effective ness	Long-term Reliability	Imple-ment-ability	Implemen-tation Risk	Cost(2)		
Functional Unit 1 – Riverbank Soil								
Metals, pesticides, VOCs, dioxins	Excavation, capping, and stabilization	*NA*	*NA*	*NA*	*NA*	*NA*	Excavation, capping, and stabilization is the presumed remedy of the Riverbank FU. The Riverbank FU will be addressed in accordance with ASAOC for River Mile 7 West.	Yes
Functional Unit 2 – Site-wide Surface and Near-Surface Soil								
Metals and pesticides – LtGW, Metals (Arsenic) and pesticides – Direct exposure. Depth interval: surface to 15 feet bgs.	Institutional controls	5	5	5	3	5	Institutional controls are administrative measures such as signage, a soil management plan, restrictions on the beneficial reuse of environmental media, fences to prevent access and restrict exposure, security cameras, maintaining industrial land use, etc. Institutional controls are likely components of most alternatives.	Yes
	Excavation	5	5	2	2	2	Excavation includes offsite disposal, which removes impacted media from the site. The RD will identify the appropriate depth of excavation. The entire FU (nearly the entire site) would be excavated, requiring substantial backfill. Rankings are for excavation of the entire site as a stand-alone alternative. Excavation of focused areas of the FU for source control and implementation of other technologies is possible. Excavation would be effective and reliable to minimize potential worker exposure and LtGW. Presence of site infrastructure (i.e., GWET system) reduces implementability on Lots 3 and 4. Health and safety hazards of excavation constitute implementation risk. Excavation of surface soil across the entire site is unlikely to be cost effective.	Yes
	Capping	4	4	4	3	4	A cap is a protective cover that limits infiltration and/or prevents direct contact with soil. Sampling and analysis conducted during RD would identify relevant pathways, construction, and extent of a cap. Capping is highly effective at preventing direct exposure and LtGW, depending on the capping material. Capping is reliable with proper maintenance and easy to implement. A cap is consistent with likely future site development for industrial use and is less expensive than active treatment technologies. An existing cap, constructed as an interim remedy, covers much of the site. The FS will evaluate retention of existing caps as a final remedial technology.	Yes
	In situ phytoremediation	1	1	1	2	3	Phytoremediation refers to use of plants to assimilate or enhance degradation of amenable COCs. Phytoremediation is a technology to treat certain metals and VOCs in soil. Phytoremediation is of uncertain effectiveness for arsenic and pesticides. Regulatory implementability may be low due to requirements of the City Portland Willamette Greenway Plan and preference for maintaining industrial land use of the site. Implementation risk is high (low ranking) due to exposures during implementation and possible release and spread of colonizing plants. Phytoremediation is not retained for consideration in the FS due to low effectiveness, low reliability, and likely low implementability.	No
	Enhanced aerobic/ anaerobic biodegradation	3	3	2	3	2	Enhanced biodegradation in unsaturated soil uses indigenous or augmented microorganisms to degrade target COCs in soil. Enhanced aerobic and anaerobic biodegradation rely on delivery of electron acceptors (aerobic) or electron donors (anaerobic) and maintaining suitable redox conditions and soil moisture to be effective. The COCs at FU-2 present challenges to both aerobic and anaerobic biological treatment. Pesticides and some VOCs may be amenable to anaerobic biological treatment. Aerobic biological treatment may be appropriate for some VOCs and the dechlorinated intermediates from anaerobic degradation. For these reasons, a two-step process may be necessary for a biodegradation remedy to be effective. Enhanced biodegradation requires adequate moisture, nutrient balance, and pH. Maintaining proper conditions to support a two-step in situ biological process makes implementability complex. In situ mixing/tilling may enhance amendment distribution and contact and improve effectiveness.	Yes
	ISCO	4	4	3	3	3	Advanced ISCO (by processes that produce reactive radicals) treats COCs by oxidation. ISCO can be effective to treat VOCs and pesticides and stabilize dissolved metals (e.g., arsenic) through precipitation. The high capital cost of implementing ISCO site wide reduces its cost effectiveness, but rapid treatment eliminates long-term O&M costs of other technologies. ISCO can be combined simultaneously or sequentially with ISCR, ISCS, and ISSS by tilling or otherwise mixing amendments into the soil to the target depth.	Yes
	ISCR	4	4	3	3	3	ISCR primarily uses iron (e.g., ZVI) and/or sulfur-based reducing processes to chemically reduce amenable COCs. ISCR can dechlorinate pesticides but may require natural attenuation of intermediate compounds. ISCR may be only marginally effective to immobilize arsenic because arsenic sulfide minerals formed by ISCR have variable solubility/mobility. The high cost of implementing ISCR site wide may reduce its cost effectiveness. ISCR can be combined simultaneously or sequentially with ISCS or ISSS by tilling or otherwise mixing amendments into the near-surface soil.	Yes
	ISCS	4	3	3	3	3	In situ chemical stabilization uses reagents to cause a chemical reaction that reduces the leachability of COCs. The reaction either chemically immobilizes COCs or reduces their solubility by forming, for example, insoluble metal hydroxides, carbonates, or silicates. ISCS can be combined simultaneously or sequentially with ISCO or ISCR by tilling or otherwise mixing amendments into the near-surface soil.	Yes
	ISSS	4	3	3	4	3	ISSS solidifies contaminated soil to restrict mobility of the COCs in soil. ISSS typically encapsulates the contaminated medium in a solid material that is impermeable to water. ISSS typically uses Portland cement or other additive to provide geotechnical stability and entrain COCs in a low-strength concrete monolith, which prevents contamination from leaching into groundwater. ISSS can be combined simultaneously or sequentially with ISCO or ISCR by tilling or otherwise mixing amendments into the near-surface soil.	Yes

Contaminant of Concern - COCs	Technology	Preliminary Remedy Selection Balancing Factors (Rated 1-5)[1] Effectiveness	Long-term Reliability	Implementability	Implementation Risk	Cost[2]	Comments	Retained Yes/No
Functional Units 3 – Acid Plant Vicinity Surface and Near-Surface Soil								
Metals, pesticides, and VOCs in soil – LtGW. Depth interval: surface to 15 feet bgs.	Institutional controls	5	5	5	3	5	See FU-2 for technology description.	Yes
	Excavation	5	5	2	2	2	See FU-2 for technology description. The RD will identify the appropriate depth and extent of excavation. If excavation adequately removes the source, excavation would be effective and reliable to minimize potential LtGW. Capping (or combination of other technologies) may be necessary to prevent infiltration and LtGW of residual contamination below 3 feet bgs in the areas where further excavation is not feasible. Presence of site infrastructure (i.e., the GWET system) reduces implementability on Lots 3 and 4. Excavation of surface soil and other focused areas within an FU may be cost effective to remove mass.	Yes
	Capping	4	4	5	5	5	See FU-2 for technology description. FU-3 would be capped with a protective cover to limit infiltration and/or prevent direct contact with soil. Sampling and analysis conducted during RD would identify relevant pathways, construction, and extent of a cap. Capping is effective at preventing direct exposure and LtGW. Capping is reliable with proper maintenance and easy to implement. A cap is consistent with likely future site development for industrial use and is inexpensive, as compared to other active treatment technologies. A cap for FU-3 has higher ranking than FU-2 due to its smaller area. A cap constructed as an interim remedy covers much of the site. The FS will evaluate retention of existing caps as a final remedial technology.	Yes
	In situ soil flushing	2	1	4	1	3	In situ soil flushing typically uses water with a surfactant or other amendment to enhance the mobility of a COC, flush COCs to groundwater, and then extract and re-inject the treated and amended groundwater in a closed-loop system. Effectiveness of soil flushing relies on uniform application of water, an amendment applicable to the range of COC properties, and mobility of COCs. Achieving uniform mobility of COCs would be difficult, making long-term reliability low. Flushing would be implementable on an open site with bare ground. A cap would be incompatible with in situ soil flushing. Implementation risk of in situ soil flushing includes mobilization of COCs to groundwater without adequate capture. Soil flushing is not retained for FU-3.	No
	In situ thermal treatment	3	4	4	3	2	In situ thermal treatment uses electrical resistance, thermal conductance, or injected steam to heat COCs to vapors. SVE recovers COC vapors from the soil gas. Vapor treatment is typically required. Thermal treatment is commonly effective and reliable on VOCs and pesticides in soil, but not for metals. Thermal treatment is expensive to implement, but the short duration of thermal treatment can be cost effective if treatment removes the source and achieves RAOs, while significantly reducing long-term O&M costs.	Yes
	SVE	2	3	2	1	4	SVE recovers COC vapors from the soil gas. SVE in FU-3 would apply to VOCs only. SVE would not be effective on pesticides or metals. Heterogeneity of fill and presence of silts and clays could result in short-circuiting of subsurface airflow, resulting in low effectiveness of SVE. Previous SVE interim remedial action had limited effectiveness for treating VOCs in soil. Because SVE would not be effective to treat metals and high boiling point pesticides, and because the SVE interim action was minimally effective on VOCs, SVE is not retained for FU-3.	No
	Enhanced aerobic/ anaerobic biodegradation	1	3	2	2	2	See FU-2 for technology description. Bioremediation is likely redundant or incompatible with remedies for DNAPL portions of the acid plant vicinity. Enhanced biodegradation would not be effective as primary treatment for FU-3, but it is retained as a possible polishing step after source mass is depleted.	Yes
	ISCO	4	3	3	3	3	See FU-2 for technology description. FU-3 COCs are similar to FU-2, but implementation depth interval is deeper (15 feet), or as determined by sampling and analysis during RD. ISCO (and similar technologies) may be implemented by mechanical or hydraulic mixing of amendments throughout the soil volume. For example, jet grouting is a method of using a drill rig to inject a grout (or other amendment) into interconnected pore spaces of a formation. Jet grouting provides aggressive mixing of soil and delivery of amendments. The FS will evaluate a variety of delivery and mixing methods.	Yes
	ISCR	4	3	3	3	3	See FU-2 for technology description. See FU-3 ISCO for additional explanation and description of process options.	Yes
	ISCS	4	3	3	3	3	See FU-2 for technology description. See FU-3 ISCO for additional explanation and description of process options.	Yes
	ISSS	4	4	3	3	3	See FU-2 for technology description. See FU-3 ISCO for additional explanation and description of process options.	Yes
Functional Unit 4 – Acid Plant Area Surface and Near-Surface Soil								
Metals, pesticides, VOCs, and DNAPL in soil – LtGW. Pesticides – Direct exposure. Depth interval: surface to 15 feet bgs.	Institutional controls	5	5	5	3	5	See FU-2 for technology description.	Yes
	Excavation	5	5	4	2	2	See FU-2 for technology description. Excavation depth would be up to 15 feet (excavation worker), or to the water table. The RD would refine the actual excavation depth. Excavation would be effective and reliable to minimize potential worker exposure and LtGW	Yes
	Capping	4	5	5	5	5	See FU-2 for technology description. Capping is highly effective at preventing direct exposure and LtGW. Capping is reliable with proper maintenance and easy to implement. A cap is consistent with likely future site development for industrial use and is inexpensive, as compared to other active treatment technologies. A cap and liner constructed as an interim remedy cover much of the FU-4. The FS will evaluate retention of existing caps as a final remedial technology.	Yes
	In situ soil flushing	2	2	4	2	2	See FU-3 for technology description. Effectiveness of soil flushing relies on uniform application of water, amendment applicable to the range of COC properties, and mobility of COCs. Achieving uniform mobility of COCs would be difficult, making long-term reliability low. Flushing can be	No

Contaminant of Concern - COCs	Technology	Preliminary Remedy Selection Balancing Factors (Rated 1-5)[(1)]					Comments	Retained Yes/No
		Effective ness	Long-term Reliability	Imple-ment-ability	Implemen-tation Risk	Cost[(2)]		
							implementable on an open site with bare ground. The existing cap would be incompatible with in situ soil flushing. Implementation risk of in situ soil flushing includes mobilization of COCs to groundwater without adequate capture. Soil flushing is not retained for FU-4.	
	In situ thermal treatment	3	4	4	3	3	See FU-3 for technology description. Thermal treatment is commonly effective and reliable on VOCs and pesticides in soil, though not for metals. Thermal treatment is expensive to implement, but the short duration of thermal treatment can be cost effective if treatment removes the source and achieves RAOs, while significantly reducing long-term O&M costs	Yes
	SVE	2	2	2	1	4	See FU-3 for technology description. SVE would not be effective on pesticides or metals. Previous SVE interim remedial action had limited effectiveness for treating VOCs in soil. Heterogeneity of fill and presence of silts and clays could result in short-circuiting of subsurface airflow, resulting in low effectiveness of SVE. Because SVE would not be effective to treat metals and high boiling point pesticides, and because the SVE interim action was minimally effective on VOCs, SVE is not retained for FU-4.	No
	Enhanced aerobic/ anaerobic biodegradation	1	2	2	2	2	See FU-2 for technology description. Bioremediation is not effective on DNAPL. Enhanced biodegradation would not be effective as primary treatment for FU-3, but it is retained as a possible polishing step after source mass is depleted.	Yes
	ISCO	4	4	4	4	3	See FU-2 for technology description. ISCO and combined technologies can be effective to treat VOCs and metals including arsenic with modifications to the soil to prevent leaching of COCs to groundwater. Application of ISCO in FU-4 would likely include mixing of amendments by mechanical or hydraulic methods. For example, see FU-3 for discussion of jet grouting.	Yes
	ISCR	3	3	3	3	3	See FU-2 for technology description. See FU-3 ISCO for additional explanation and description of process options.	Yes
	ISCS	4	3	3	3	3	See FU-2 for technology description. See FU-3 ISCO for additional explanation and description of process options.	Yes
	ISSS	4	3	3	3	3	See FU-2 for technology description. See FU-3 ISCO for additional explanation and description of process options.	Yes
Functional Unit 5 – Lots 1 and 2 Shallow and Intermediate Groundwater Zones								
Metals, pesticides, dioxins, VOCs, and chloride in shallow and intermediate zones Depth interval: water table to top of deep zone	Institutional controls	5	5	5	3	5	See FU-2 for technology description.	Yes
	Monitored natural attenuation	3	3	5	3	5	MNA uses groundwater monitoring data and knowledge and evidence of attenuation mechanisms to assess the rate and process of COC attenuation. MNA is a viable remediation technology if monitoring demonstrates that concentrations are trending toward cleanup goals or the remedy is otherwise achieving RAOs by specific attenuation mechanisms. MNA may be combined with active treatment, capping, or other technologies to achieve RAOs. Upland groundwater remedies interface with the in-water remedy, such as the in-water reactive sediment cap. MNA can be reliable if processes continue to target RAOs. MNA is easy to implement and cost effective. Possible ongoing transport and exposure during MNA may constitute implementation risk.	Yes
	Permeable reactive barrier	4	5	4	4	4	A permeable reactive barrier commonly consists of an excavated trench backfilled with treatment media or groundwater zone perfused with treatment media that sorbs or otherwise treats COCs in groundwater that flows through the barrier. Reactive barriers can use many types of media, including GAC, ZVI, and sorptive resins. A barrier installed upslope of the riverbank to intercept the target depth of groundwater would treat groundwater before it reaches the river. Sorptive media may be considered instead of ZVI due to the possible production of divalent iron above hotspot criteria. It is possible that a two-stage PRB would be considered, as is a common application. Bench testing during RD will assess effectiveness and possible adverse impacts of barrier media. The COCs in groundwater beneath Lots 1 and 2 are amenable to sorption and ISCR. Lots 1 and 2 span the northwest end of the site, where groundwater is shallow, making installation of reactive barrier simple and cost effective.	Yes
	In situ thermal treatment	2	2	2	3	1	See FU-3 for technology description. Thermal treatment can be effective for removing VOCs, dioxins, and pesticides. However, because some of the COCs would require temperatures above the boiling point of water, either dewatering or intense energy would be necessary for effective thermal treatment in groundwater. Thermal treatment is not effective for metals. Due to the high cost in comparison to other relevant technologies, thermal treatment is not retained for FU-5.	No
	Enhanced aerobic/ anaerobic biodegradation	3	3	2	3	2	Enhanced biodegradation in groundwater uses indigenous or augmented microorganisms to degrade target COCs. Enhanced aerobic and anaerobic biodegradation rely on delivery of electron acceptors (aerobic) or electron donors (anaerobic) and maintaining suitable redox conditions to be effective. The COCs at FU-5 present challenges to both aerobic and anaerobic biological treatment. Pesticides and some VOCs may be amenable to anaerobic biological treatment. Aerobic biological treatment may be appropriate for some VOCs and the dechlorinated intermediates from anaerobic degradation. For these reasons, a two-step process is often implemented. Enhanced biodegradation requires adequate microbial nutrients and pH. Maintaining proper conditions to support a two-step in situ biological process makes implementability complex.	Yes
	ISCO	4	4	4	4	3	See FU-2 for technology description. ISCO execution would be similar for soil and groundwater FUs. ISCO and possible combined technologies (see below) can be effective to treat VOCs and metals including arsenic with possible modifications to the groundwater formation to prevent transport of COCs in groundwater. Sampling and analysis during RD would determine the target depth interval. The effectiveness of ISCO relies on distribution and contact with the reagents, which can be difficult in deeper groundwater Application in groundwater would likely include mixing of amendments by mechanical or hydraulic methods throughout the impacted soil and groundwater volume. For example, jet grouting is a method of using a drill rig to inject a grout (or other amendments) into interconnected pore spaces of a groundwater formation Jet grouting provides aggressive mixing of soil and delivery of amendments. The FS will evaluate a variety of delivery and mixing methods.	Yes

Table 2: Technology Screening Table
***Former* Arkema Facility, Portland, Oregon**
Feasibility Study Technology Screening Memo

Contaminant of Concern - COCs	Technology	Preliminary Remedy Selection Balancing Factors (Rated 1-5)[1]					Comments	Retained Yes/No
		Effectiveness	Long-term Reliability	Imple-ment-ability	Implemen-tation Risk	Cost[2]		
	ISCR	3	3	3	3	3	See FU-2 for technology description. See FU-5 ISCO (above) for additional explanation and description of process options.	Yes
	ISCS	4	3	3	3	3	See FU-2 for technology description. See FU-5 ISCO (above) for additional explanation and description of process options.	Yes
	ISSS	4	3	3	3	3	See FU-2 for technology description. See FU-5 ISCO (above) for additional explanation and description of process options.	Yes
	Hydraulic control	3	3	4	4	4	Hydraulic control refers to groundwater pumping or containment to minimize transport and exposure of COCs in groundwater. In this context, hydraulic control is an engineering control. The existing GWET system, which includes a groundwater pump and treat system and a barrier wall, provides hydraulic control. If the GWET system meets performance standards, the GWET pumping system is a likely component of all hydraulic control groundwater alternatives in the areas where it currently operates. The cost effectiveness of hydraulic control reflects that the GWET system is installed and operational in the stated functional unit. The GWET system is not a viable long-term alternative, due to high costs of O&M, as compared to passive treatment technologies, like a PRB. Hydraulic control (the GWET system) is retained as an interim component of remedial alternatives in shallow and intermediate groundwater.	Yes
Functional Unit 6 – Southern Riverside Portion of Lot 3 Shallow and Intermediate Groundwater Zones								
VOCs and pesticides in shallow groundwater, chloride, and metals in shallow and intermediate groundwater Depth interval: water table to top of deep zone	Institutional controls	5	5	5	3	5	See FU-2 for technology description.	Yes
	Monitored natural attenuation	4	2	5	2	5	See FU-5 for technology description. MNA can be reliable if processes continue to target RAOs. MNA is easy to implement and cost effective. Possible ongoing transport and exposure during MNA may constitute implementation risk. The low effectiveness ranking reflects the possibly long timeframe to naturally attenuate VOCs and pesticides.	Yes
	Permeable reactive barrier	5	5	5	5	4	See FU-5 for technology description. A sorptive or sequestrant barrier may be preferred over a ZVI barrier due to possible production of divalent iron above hotspot criteria. Bench testing during RD would assess possible adverse impacts of barrier media. A two-stage PRB may be considered.	Yes
	In situ thermal treatment	2	2	2	3	1	See FU-3 for technology description. Thermal treatment can be effective for treating VOCs, dioxins, and pesticides. However, because some of the COCs would require temperatures above the boiling point of water, either dewatering or intense energy would be necessary for effective thermal treatment in groundwater. Thermal treatment is not effective for metals. Due to the high cost in comparison to other relevant technologies, thermal is not retained for FU-6.	No
	Enhanced aerobic/ anaerobic biodegradation	3	3	2	3	2	See FU-5 for technology description. Enhanced aerobic and anaerobic biodegradation rely on delivery of electron acceptors (aerobic) or electron donors (anaerobic) and maintaining suitable redox conditions to be effective. The COCs at FU-5 present challenges to both aerobic and anaerobic biological treatment. It may be possible to implement a two-step biological treatment process within the saturated zone, but effectiveness may decrease with increasing depth to challenges of amendment delivery. Soil and groundwater conditions downgradient of ISCO or soil stabilization may enhance MNA. Enhanced aerobic biological treatment can be expensive due to difficulty in delivering sufficient electron acceptor. Conversely, sources of electron donor (for anaerobic biological treatment) are abundant. Field-scale testing may be necessary to demonstrate the two-step process is possible.	Yes
	ISCO	4	4	4	4	3	See FU-2 for technology description. ISCO execution would be similar for soil and groundwater FUs. ISCO and possible combined technologies (see below) can be effective to treat VOCs and metals including arsenic with possible modifications to the groundwater formation to prevent transport of COCs in groundwater. The implementation interval would be determined by sampling and analysis during RD. Implementation in groundwater would likely include mixing of amendments by mechanical or hydraulic methods throughout the impacted soil and groundwater volume. For example, jet grouting is a method of using a drill rig to inject a grout (or other amendments) into interconnected pore spaces of a groundwater formation Jet grouting provides aggressive mixing of soil and delivery of amendments. The effectiveness of ISCO and similar technologies via injections relies on distribution and contact with the reactive reagents, which can be difficult in deeper aquifers. The FS will evaluate a variety of delivery and mixing methods.	Yes
	ISCR	4	3	3	3	3	See FU-2 for technology description. See FU-6 ISCO (above) for additional explanation and description of process options.	Yes
	ISCS	4	3	3	3	3	See FU-2 for technology description. See FU-6 ISCO (above) for additional explanation and description of process options.	Yes
	ISSS	4	3	3	3	3	See FU-2 for technology description. See FU-6 ISCO (above) for additional explanation and description of process options.	Yes
	Hydraulic control	3	3	4	3	3	See FU-5 for technology description. The reliability of imposing hydraulic control in deeper groundwater is uncertain.	Yes
Functional Unit 7 – Uplands Portion of Lots 3 and 4 Shallow, Intermediate, and Deep Groundwater Zones								
Metals, dioxins, and pesticides in shallow intermediate, and deep groundwater and chloride	Institutional controls	5	5	5	3	5	See FU-2 for technology description.	Yes
	Monitored natural attenuation	2	2	5	2	5	See FU-5 for technology description. MNA can be reliable if processes continue to target RAOs. MNA is easy to implement and cost effective. Possible ongoing transport and exposure during MNA may constitute implementation risk. The low effectiveness ranking reflects the possibly long timeframe to naturally attenuate VOCs and pesticides.	Yes

Contaminant of Concern - COCs	Technology	Preliminary Remedy Selection Balancing Factors (Rated 1-5)[1]					Comments	Retained Yes/No
		Effective ness	Long-term Reliability	Imple-ment-ability	Implemen-tation Risk	Cost[2]		
in shallow and intermediate groundwater Depth interval: water table to top of basalt	Permeable reactive barrier (GAC)	5	5	5	5	3	See FU-5 for technology description. A sorptive or sequestrant barrier may be preferred over a ZVI barrier due to possible production of divalent iron above hotspot criteria. Bench testing during RD would assess possible adverse impacts of barrier media. A two-stage PRB may be considered. A PRB installed to address deeper groundwater would be more expensive, as compared to shallow groundwater (e.g., FU-5).	Yes
	Enhanced aerobic/ anaerobic biodegradation	3	3	2	3	2	See FU-5 for technology description. It may be possible to implement a two-step biological treatment process within the saturated zone, but effectiveness may decrease with increasing depth to challenges of amendment delivery. Soil and groundwater conditions downgradient of ISCO or soil stabilization may enhance MNA. Enhanced aerobic biological treatment can be expensive due to difficulty in delivering sufficient electron acceptor. Conversely, sources of electron donor (for anaerobic biological treatment) are abundant. Field-scale testing may be necessary to demonstrate the two-step process is possible.	Yes
	ISCO	4	4	4	4	3	See FU-2 for technology description. ISCO execution would be similar for soil and groundwater FUs. ISCO and possible combined technologies (see below) can be effective to treat VOCs and metals including arsenic with possible modifications to the groundwater formation to prevent transport of COCs in groundwater. The implementation interval would be determined by sampling and analysis during RD. The effectiveness of ISCO relies on distribution and contact with the reagents, which can be difficult in deeper groundwater. Implementation in groundwater would include mixing of amendments by mechanical or hydraulic methods or reagent injection throughout the impacted soil and groundwater volume. For example, jet grouting is a method of using a drill rig to inject a grout (or other amendments) into interconnected pore spaces of a groundwater formation. Jet grouting provides aggressive mixing of soil and delivery of amendments. The FS will evaluate a variety of delivery and mixing methods.	Yes
	ISCR	3	3	3	3	3	See FU-2 for technology description. See FU-7 ISCO (above) for additional explanation and description of process options.	Yes
	ISCS	4	3	3	3	3	See FU-2 for technology description. See FU-7 ISCO (above) for additional explanation and description of process options.	Yes
	ISSS	4	3	3	3	3	See FU-2 for technology description. See FU-7 ISCO (above) for additional explanation and description of process options.	Yes
	Hydraulic control	3	3	4	3	3	See FU-5 for technology description. The reliability of imposing hydraulic control in deeper groundwater is uncertain.	Yes
Functional Unit 8 – Northern Riverside Portion of Lots 3 and 4 Shallow, Intermediate, and Deep Groundwater Zones								
Metals, chloride, pesticides, and VOCs in shallow, intermediate, and deep groundwater, and dioxins in the shallow zone Depth interval: water table to top of basalt	Institutional controls	5	5	5	3	5	See FU-2 for technology description.	Yes
	Monitored natural attenuation	2	2	5	2	5	See FU-5 for technology description. Upland groundwater remedies interface with the in-water remedy, such as the in-water reactive sediment cap. MNA can be reliable if processes continue to target RAOs. MNA is easy to implement and cost effective. Possible ongoing transport and exposure during MNA may constitute implementation risk. The low effectiveness ranking reflects the possibly long timeframe to naturally attenuate VOCs and pesticides.	Yes
	In situ thermal treatment	2	2	2	3	1	See FU-3 for technology description. Thermal treatment can be effective for removing VOCs, dioxins, and pesticides. However, because some of the COCs would require temperatures above the boiling point of water, either dewatering or intense energy would be necessary for effective thermal treatment in groundwater. Thermal is not effective for metals. Due to the excessive cost in comparison to other relevant technologies, thermal is not retained for FU8.	No
	Enhanced aerobic/ anaerobic biodegradation	3	3	2	3	2	See FU-5 for technology description. Enhanced aerobic and anaerobic biodegradation rely on delivery of electron acceptors (aerobic) or electron donors (anaerobic) and maintaining suitable redox conditions to be effective. The COCs at FU-5 present challenges to both aerobic and anaerobic biological treatment. It may be possible to implement a two-step biological treatment process within the saturated zone, but effectiveness may decrease with increasing depth to challenges of amendment delivery. Soil and groundwater conditions downgradient of ISCO or soil stabilization may enhance MNA. Enhanced aerobic biological treatment can be expensive due to difficulty in delivering sufficient electron acceptor. Conversely, sources of electron donor (for anaerobic biological treatment) are abundant. Field-scale testing may be necessary to demonstrate the two-step process is possible.	Yes
	ISCO	3	3	4	3	3	See FU-2 for technology description. ISCO execution would be similar for soil and groundwater FUs. ISCO and possible combined technologies (see below) can be effective to treat VOCs and metals including arsenic with possible modifications to the groundwater formation to prevent transport of COCs in groundwater. Sampling and analysis during RD would determine the implementation interval. The effectiveness of ISCO relies on distribution and contact with the reagents, which can be difficult in deeper groundwater. Implementation in groundwater would include mixing of amendments by mechanical or hydraulic methods or reagent injection throughout the impacted soil and groundwater volume. For example, jet grouting is a method of using a drill rig to inject a grout (or other amendments) into interconnected pore spaces of a groundwater formation. Jet grouting provides aggressive mixing of soil and delivery of amendments. The FS will evaluate a variety of delivery and mixing methods. Secondary water quality concerns (i.e., non-targeted reactions with the natural aquifer) can create some implementation risk. Bench or field-scale testing would be required to assess process options.	Yes
	ISCR	2	3	4	3	2	See FU-2 for technology description. See FU-8 ISCO (above) for additional explanation and description of process options.	Yes
	ISCS	3	3	4	3	3	See FU-2 for technology description. See FU-8 ISCO (above) for additional explanation and description of process options.	Yes
	ISSS	3	3	4	3	3	See FU-2 for technology description. See FU-8 ISCO (above) for additional explanation and description of process options.	Yes

Table 2: Technology Screening Table
***Former* Arkema Facility, Portland, Oregon**
Feasibility Study Technology Screening Memo

Contaminant of Concern - COCs	Technology	Preliminary Remedy Selection Balancing Factors (Rated 1-5)[1]					Comments	Retained Yes/No
		Effectiveness	Long-term Reliability	Implement-ability	Implementation Risk	Cost[2]		
	Hydraulic control	3	3	4	3	3	See FU-5 for technology description. The reliability of imposing hydraulic control in deeper groundwater may be less certain. If other in situ treatments (such as ISCO or EISB) are implemented near the existing GWET, the resultant geochemistry of the extracted groundwater may affect the GWET treatment, significantly increasing the GWET O&M cost. Hydraulic control is currently implemented as an interim remedy in the shallow and intermediate zones of FU-8.	Yes
Functional Unit 9 – Acid Plant Area Shallow, Intermediate, and Deep Groundwater Zones								
Metals, chloride, pesticides, and VOCs in shallow, intermediate, and deep groundwater. Dioxins and DNAPL in shallow groundwater Depth interval: water table to top of basalt	Institutional controls	5	5	5	3	5	See FU-2 for technology description. Institutional controls in deep groundwater would include restrictions on drilling and groundwater use.	Yes
	Monitored natural attenuation	2	2	5	2	5	See FU-5 for technology description. MNA would be used in combination with other technologies. Some of the COCs are not easily degraded by the intrinsic bacteria and will remain in GW for many years. The low effectiveness ranking reflects the possibly long timeframe to naturally attenuate VOCs and pesticides.	Yes
	In situ thermal treatment	2	2	2	3	1	See FU-3 for technology description. Thermal treatment can be effective for removing VOCs, dioxins, and pesticides. However, because some of the COCs would require temperatures above the boiling point of water, either dewatering or intense energy would be necessary. Thermal is not effective for metals. Due to the excessive cost in comparison to other relevant technologies, thermal is not retained for FU-9.	No
	Enhanced aerobic/ anaerobic biodegradation	3	3	2	3	2	See FU-5 for technology description. It may be possible to implement a two-step biological treatment process within the saturated zone, but effectiveness may decrease with increasing depth to challenges of amendment delivery. Soil and groundwater conditions downgradient of ISCO or soil stabilization may enhance MNA. Enhanced aerobic biological treatment can be expensive due to difficulty in delivering sufficient electron acceptor. Conversely, sources of electron donor (for anaerobic biological treatment) are abundant. Field-scale testing may be necessary to demonstrate the two-step process is possible.	Yes
	ISCO	3	3	4	3	3	See FU-2 for technology description. ISCO execution would be similar for soil and groundwater FUs. ISCO and possible combined technologies (see below) can be effective to treat VOCs and metals including arsenic with possible modifications to the groundwater formation to prevent transport of COCs in groundwater. Sampling and analysis during RD would determine the implementation interval. The effectiveness of ISCO relies on distribution and contact with the reagents, which can be difficult in deeper groundwater. Implementation in groundwater would include mixing of amendments by mechanical or hydraulic methods or reagent injection throughout the impacted soil and groundwater volume. For example, jet grouting is a method of using a drill rig to inject a grout (or other amendments) into interconnected pore spaces of a groundwater formation. Jet grouting provides aggressive mixing of soil and delivery of amendments. The FS will evaluate a variety of delivery and mixing methods. Secondary water quality concerns (i.e., non-targeted reactions with the natural aquifer) can create some implementation risk. Bench or field-scale testing would be required to assess process options.	Yes
	ISCR	2	3	4	3	2	See FU-2 for technology description. See FU-9 ISCO (above) for additional explanation and description of process options.	Yes
	ISCS	3	3	4	3	3	See FU-2 for technology description. See FU-9 ISCO (above) for additional explanation and description of process options.	Yes
	ISSS	3	3	4	3	3	See FU-2 for technology description. See FU-9 ISCO (above) for additional explanation and description of process options.	Yes
	Hydraulic control	3	3	4	3	2	See FU-5 for technology description. The reliability of achieving hydraulic control in deeper groundwater is uncertain. If other in situ treatments (such as ISCO or EISB) are implemented near the existing GWET, the resultant geochemistry of the extracted groundwater may affect the GWET treatment, significantly increasing the GWET O&M cost. Hydraulic control is currently implemented as an interim remedy in the shallow and intermediate zones in of FU-9.	Yes
Functional Unit 10 – Southern Riverside Portion of Lot 4 Shallow, Intermediate, and Deep Groundwater Zones								
Metals, chloride, pesticides, VOCs, and perchlorate in shallow, intermediate, and deep groundwater Depth interval: water table to top of basalt	Institutional controls	5	5	5	3	5	See FU-2 for technology description. Institutional controls in deep groundwater would include restrictions on drilling and groundwater use.	Yes
	Monitored natural attenuation	3	3	5	3	5	See FU-2 for technology description. MNA would be used in combination with other technologies. Some of the COCs are not easily degraded by the intrinsic bacteria and will remain in GW for many years. The low effectiveness ranking reflects the possibly long timeframe to naturally attenuate VOCs and pesticides.	Yes
	Enhanced aerobic/ anaerobic biodegradation	3	3	2	3	2	See FU-5 for technology description. Aerobic biodegradation is effective on perchlorate. It may be possible to implement a two-step biological treatment process in the saturated zone, but effectiveness may decrease with increasing depth to challenges of amendment delivery. Soil and groundwater conditions downgradient of ISCO or soil stabilization may enhance MNA. Enhanced aerobic biological treatment can be expensive due to difficulty in delivering sufficient electron acceptor. Conversely, sources of electron donor (for anaerobic biological treatment) are abundant. Field-scale testing may be necessary to demonstrate the two-step process is viable.	Yes
	ISCO	4	4	4	3	3	See FU-2 for technology description. ISCO and possible combined technologies (see below) can be effective to treat VOCs and metals including arsenic with possible modifications to the groundwater formation to prevent transport of COCs in groundwater. Sampling and analysis during RD would determine the implementation interval. The effectiveness of ISCO relies on distribution and contact with the reagents, which can be difficult in deeper groundwater. Implementation in groundwater would include mixing of amendments by mechanical or hydraulic methods or reagent injection throughout the impacted soil and groundwater volume. For example, jet grouting is a method of using a drill rig to inject a grout (or other amendments) into interconnected pore spaces of a groundwater formation. Jet grouting provides aggressive mixing of soil and delivery of	Yes

Contaminant of Concern - COCs	Technology	Preliminary Remedy Selection Balancing Factors (Rated 1-5)[1]					Comments	Retained Yes/No
		Effective ness	Long-term Reliability	Imple-ment-ability	Implemen-tation Risk	Cost[2]		
							amendments. The FS will evaluate a variety of delivery and mixing methods. Secondary water quality concerns (i.e., non-targeted reactions with the natural aquifer) can create some implementation risk. Bench or field-scale testing would be required to assess process options.	
	ISCR	2	3	4	3	2	See FU-2 for technology description. See FU-10 ISCO (above) for additional explanation and description of process options.	Yes
	ISCS	3	3	4	3	3	See FU-2 for technology description. See FU-10 ISCO (above) for additional explanation and description of process options.	Yes
	ISSS	3	3	4	3	3	See FU-2 for technology description. See FU-10 ISCO (above) for additional explanation and description of process options.	Yes
	Hydraulic control	3	3	4	3	2	See FU-5 for technology description. The reliability of achieving hydraulic control in deeper groundwater is uncertain. If other in situ treatments (such as ISCO or EISB) are implemented near the existing GWET, the resultant geochemistry of the extracted groundwater may affect the GWET treatment, significantly increasing the GWET O&M cost. Hydraulic control is currently implemented as an interim remedy in the shallow and intermediate zones in of FU-10.	Yes
Functional Unit 11 – Gravel/Basalt Zone Groundwater on Lots 3 and 4								
Metals, chloride, pesticides, dioxins, and VOCs Depth interval: Gravel/ Basalt Zones	Monitored natural attenuation	2	2	5	2	5	See FU-2 for technology description. MNA would be used in combination with other technologies. Some of the COCs are not easily degraded by the intrinsic bacteria and will remain in GW for many years. Shallow and intermediate removal of COCs eliminates primary source area – contamination in low permeability strata to be monitored.	Yes
	Institutional controls	5	5	5	3	5	See FU-1 for technology description. Institutional controls in deep groundwater would include placing restrictions on water use and drilling.	Yes
	Enhanced aerobic/ anaerobic biodegradation	3	3	2	3	2	See FU-5 for technology description. It may be possible to implement a two-step biological treatment process in the saturated zone, but effectiveness may decrease with increasing depth due to challenges of amendment delivery. Soil and groundwater conditions downgradient of ISCO or soil stabilization may enhance MNA. Enhanced aerobic biological treatment can be expensive due to difficulty in delivering sufficient electron acceptor. Conversely, sources of electron donor (for anaerobic biological treatment) are abundant. Field-scale testing may be necessary to demonstrate the two-step process is viable.	Yes
	ISCO	4	4	4	3	3	See FU-2 for technology description. ISCO execution would be similar for soil and groundwater FUs. ISCO and possible combined technologies (see below) can be effective to treat VOCs and metals including arsenic with possible modifications to the groundwater formation to prevent transport of COCs in groundwater. Sampling and analysis during RD would determine the implementation interval. The effectiveness of ISCO relies on distribution and contact with the reagents, which can be difficult in deeper groundwater. Implementation in groundwater would include mixing of amendments by mechanical or hydraulic methods or reagent injection throughout the impacted soil and groundwater volume. For example, jet grouting is a method of using a drill rig to inject a grout (or other amendments) into interconnected pore spaces of a groundwater formation. Jet grouting provides aggressive mixing of soil and delivery of amendments. The FS will evaluate a variety of delivery and mixing methods. Secondary water quality concerns (i.e., non-targeted reactions with the natural aquifer) can create some implementation risk. Bench or field-scale testing would be required to assess process options.	Yes
	ISCR	2	3	4	3	2	See FU-2 for technology description. See FU-11 ISCO (above) for additional explanation and description of process options.	Yes
	ISCS	3	3	4	3	3	See FU-2 for technology description. See FU-11 ISCO (above) for additional explanation and description of process options.	Yes
	ISSS	3	3	4	3	3	See FU-2 for technology description. See FU-11 ISCO (above) for additional explanation and description of process options.	Yes
Functional Unit 12 – Deep and Gravel/Basalt Zone Groundwater on Lots 1 and 2								
Metals, chloride, pesticides, dioxins, and VOCs Depth interval: Deep and Gravel/Basalt Zones	Monitored natural attenuation	NA	NA	NA	NA	NA	Trespass plume – action by others	NA
	PRB to top of deep zone	NA	NA	NA	NA	NA	Trespass plume – action by others	NA
	Enhanced aerobic/ anaerobic biodegradation	NA	NA	NA	NA	NA	Trespass plume – action by others	NA
	ISCO	NA	NA	NA	NA	NA	Trespass plume – action by others	NA
	ISCR	NA	NA	NA	NA	NA	Trespass plume – action by others	NA
	ISCS	NA	NA	NA	NA	NA	Trespass plume – action by others	NA
	ISSS	NA	NA	NA	NA	NA	Trespass plume – action by others	NA

Table 2: Technology Screening Table
***Former* Arkema Facility, Portland, Oregon**
Feasibility Study Technology Screening Memo

Notes:

1 1 rating is poor, 5 is excellent
2 cost = cost effectiveness

AC = activated carbon, GAC = granular activated carbon
ASAOC = Administrative settlement agreement and order on consent
bgs = below ground surface
COCs = contaminants of concern
Cr-VI = chromium VI
DNAPL = dense nonaqueous-phase liquid
FU= functional unit
ESIB = enhanced in situ biological treatment
GWET = groundwater extraction and treatment (system)
ISCO = in situ chemical oxidation
ISCR = in situ chemical reduction
ISCS = in situ chemical stabilization
ISSS = in situ soil solidification
LtGW = leaching to groundwater
MCB = monochlorobenzene
MNA = monitored natural attenuation
NA = not applicable
O&M = operation and maintenance
PRB = permeable reactive barrier
RAOs = remedial action objectives
RD = remedial design
SVE = soil vapor extraction
VOCs = volatile organic compounds
ZVI = zero valent iron

References:
ERM (ERM-West, Inc.). 2009. *2009 Response to Public Comments on the Groundwater Source Control Measure Interim Remedial Measure Focused Feasibility Study* Arkema Inc. Facility, Portland, Oregon. April 2009.

Table 3: Technology Screening Table Summary
***Former* Arkema Facility, Portland, Oregon**
Feasibility Study Technology Screening Memo

	Soil Technologies					Technologies Applicable to Soil and Groundwater								Groundwater Technologies		
	Technology #1 – Excavation, Capping, and Stabilization	Technology #2 – Excavation	Technology #3 – Capping	Technology #4 – In-situ Soil Flushing	Technology #5 – Soil Vapor Extraction	Technology #6 – Institutional Controls	Technology #7 – In-situ phytoremediation	Technology #8 – ISCO	Technology #9 – ISCR	Technology #10 – ISCS	Technology #11 – ISSS	Technology #12 – Enhanced Aerobic/Anaerobic Biodegradation	Technology #13 – Thermal	Technology #14 – Monitored Natural Attenuation	Technology #15 – Permeable Reactive Barrier	Technology #16 – Hydraulic Control
Functional Unit 1	X															
Functional Unit 2		X	X			X	O	X	X	X	X	X				
Functional Unit 3		X	X	O	O	X		X	X	X	X	O	X			
Functional Unit 4		X	X	O	O	X		X	X	X	X	O	X			
Functional Unit 5						X		X	X	X	X	X	O	X	X	X
Functional Unit 6						X		X	X	X	X	X	O	X	X	X
Functional Unit 7						X		X	X	X	X	X		X	X	X
Functional Unit 8						X		X	X	X	X	X	O	X		X
Functional Unit 9						X		X	X	X	X	X	O	X		X
Functional Unit 10						X		X	X	X	X	X		X		X
Functional Unit 11						X		X	X	X	X			X		
Functional Unit 12								X	X	X	X			X	X	

Notes:
X = Retained
O = Not retained