In Situ Stabilization Pre-Design Investigation Work Plan

Arkema Inc. Facility
Portland, Oregon

PREPARED FOR
Legacy Site Services LLC

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ACRONYMS AND ABBREVIATIONS

Acronym	Description
Arkema	Arkema Inc.
COC	contaminant of concern
CSM	Conceptual Site Model
DDT	dichlorodiphenyltrichloroethane
DNAPL	dense nonaqueous-phase liquid
ERM	Environmental Resources Management, Inc.
FS	Feasibility Study
GWET	Groundwater Extraction and Treatment
HASP	Health and Safety Plan
IRAM	Interim Remedial Action Measure
ISCO	in situ chemical oxidation
ISS	in situ stabilization/solidification
ITRC	Interstate Technology and Research Council
LEAF	Leaching Environmental Assessment Framework
LSS	Legacy Site Services LLC
ODEQ	Oregon Department of Environmental Quality
PDI	Pre-Design Investigation
PID	photoionization detector
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RAO	remedial action objective
RI	Remedial Investigation
ROD	record of decision
SPLP	Synthetic Precipitate Leaching Procedure
UCS	unconfined compressive strength
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

1. INTRODUCTION

On behalf of Legacy Site Services LLC (LSS), agent for Arkema Inc. (Arkema), Environmental Resources Management, Inc. (ERM) has prepared this *In Situ Stabilization Pre-Design Investigation Work Plan* (Work Plan) for the former Arkema facility (the “Site”) located at 6400 NW Front Avenue in Portland, Oregon. The Site location is shown on Figure 1. ERM prepared this Work Plan to describe the investigation and sampling activities at the Site to inform the pre-design of Interim Remedial Action Measure (IRAM) 1. The goal of IRAM 1 is to address the monochlorobenzene source area that originated in the former Acid Plant Area of the facility (referred to as IRAM 1 Treatment Area) using in situ stabilization/solidification (ISS) and/or in situ chemical oxidation (ISCO) technologies. The treatment area of IRAM 1 focuses on dense nonaqueous-phase liquid (DNAPL) present in soil and groundwater. Implementation of the Work Plan is in accordance with the Oregon Department of Environmental Quality (ODEQ) 19 January 2024 letter (ODEQ 2024) proposing an alternative to the September 2023 *Draft Feasibility Study* (FS; ERM 2023), and as discussed at a meeting with ODEQ, LSS, and ERM on 4 March 2024.

1.1 WORK PLAN OBJECTIVES

The specific objectives of the IRAM 1 Pre-Design Investigation (PDI) are to:

1. Confirm the horizontal and vertical extent of DNAPL (e.g., free product, blebs, ganglia) present within the IRAM 1 Treatment Area
2. Evaluate the amount of reagents (cement and others as defined in the treatability study) to be added to the various soil types during ISS/ISCO within the IRAM 1 Treatment Area to achieve the target reduction in hydraulic conductivity and/or chemical oxidation of approximately two to three orders of magnitude and/or sufficient destruction of monochlorobenzene
3. Evaluate the effectiveness of various remedial agents and the amount of such remedial agents that may be added along with cement during ISS

To meet these objectives, LSS proposes to complete soil borings to:

- Log soil types and elevations
- Conduct visual inspection of soil cores for the presence or absence of DNAPL
- Collect samples to analyze chlorobenzene concentration
- Collect soil samples to perform bench-scale treatability studies in support of the Preliminary Design of IRAM 1
- Use DyeLIF™ to screen for the presence or absence of DNAPL in situ

The DyeLIF™ study, along with the ISS/ISCO bench-scale study results and evaluation, will be used to evaluate the feasibility of ISS, and the mix design if it is implemented. These data will also be used to enhance the existing Conceptual Site Model (CSM) and will be reported in the Preliminary Design Report for IRAM 1.

1.2 WORK PLAN ORGANIZATION

The Work Plan is organized as follows:

- Section 1 – Introduction
- Section 2 – Scope of Work
- Section 3 – Reporting
- Section 4 – Schedule
- Section 5 – References

1.3 SITE LOCATION AND SETTING

The Site is described in further detail in the *Upland Remedial Investigation Report* (RI Report; ERM 2005), the *Preliminary Design Investigation for the GWET Wellfield Enhancement* (PDI Report; ERM 2021), and the FS (ERM 2023). This section summarizes the information contained in these reports.

The Site is located at 6400 NW Front Avenue in the northwest industrial area of Portland, Oregon. The Site is located at approximately river-mile 7.5 of the river in the Guild's Lake Industrial Sanctuary (formerly the Northwest Portland Industrial Sanctuary), zoned and designated "IH" for heavy industrial use. The Site is bordered on the east by the Willamette River, on the south by CertainTeed Roofing Products Company, and on the north and west by Front Avenue. The Site is divided into Lots 1 through 4 and Tract A along the river. For reference, a Layout Map is included as Figure 2.

The Site is generally flat with surface elevations ranging from approximately 25 to 38 feet North American Vertical Datum of 1988. Most of the Site is surrounded by security fencing. The northern portion of the Site includes Lots 1 and 2 and is relatively undeveloped. No manufacturing has occurred on Lots 1 and 2 (ERM 2005). The southern portion of the Site includes Lots 3 and 4, which comprise approximately two-thirds of the Site (39 acres). The Site has historically conducted manufacturing in the southern portion of the Site, and has developed Lots 3 and 4 with buildings, paved roads, rail spurs, and associated tanks and piping to support manufacturing processes. Tract A is a narrow strip of property between the top of the bank and the mean high-water line along the entire riverbank of the Site.

The surficial geology in the Site area is characterized by fill and alluvial deposits of the Willamette River. Alluvial deposits are underlain by bedrock of the Columbia River Basalt Group. Groundwater occurs in six distinct water-bearing zones beneath the Site. These water-bearing zones have been designated as the Shallow Zone, Shallow-Intermediate Silt Zone, Intermediate Zone, Deep Zone, and Gravel/Basalt Zone. The water-bearing zones are described in further detail in the PDI Report (ERM 2021).

1.4 SITE HISTORY AND DESCRIPTION

Starting in 1941, various chemicals were produced at the facility including: sodium chlorate, potassium chlorate, chlorine, sodium hydroxide, dichlorodiphenyltrichloroethane (DDT), sodium orthosilicate, magnesium chloride hexahydrate, ammonia, ammonium perchlorate, sodium perchlorate, and hydrochloric acid. Most recently, the facility was a chlor-alkali plant until the plant shut down in 2001 and the plant was decommissioned and dismantled in 2004. The RI Report (ERM 2005) described historical Site operation and manufacturing processes.

Currently, most of the Site is paved, gravel-covered/capped, or covered with building foundations. The only structures currently present are the building constructed to house the Groundwater Extraction and Treatment (GWET) system, three small motor-control buildings, a temporary trailer used as the Site office, and the original plant administration building. The only current activities at the Site are general maintenance and those associated with remediation.

1.5 NATURE AND EXTENT OF IRAM 1 TREATMENT AREA

The IRAM 1 Treatment Area includes the former Manufacturing Process Residue pond and overflow trench where disposal of spent chlorobenzene (i.e., DNAPL) occurred historically, as well as areas where soil and groundwater are impacted by DNAPL from the former Manufacturing Process Residue pond. This area also contains soils impacted by metals and pesticides at concentrations that exceed criteria for both direct exposure and leaching to groundwater pathways as well as volatile organic compounds (VOC) in soil that exceed leaching to groundwater criteria. This area also contains metals, chloride, VOCs, and pesticides in the Shallow, Intermediate, and Deep Zones; and furans and DNAPL in the Shallow Zone. The historical site layout showing the IRAM 1 Treatment Area is included on Figure 2. Historical operation areas are depicted on Figures 3 and 4.

1.6 INTERIM REMEDIAL ACTION MEASURE – REGULATORY BASIS

The ODEQ-approved *Final Modification Revised Upland Feasibility Study Work Plan* (ERM 2022) lists the Site-specific remedial action objectives (RAO), as follows.

- 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, 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 contaminants of concern (COC) in surface soil and riverbank soil to accumulate in 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 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 DNAPL to act as a continuing source of 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 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 river to prevent accumulation of COCs in river sediment above risk-based levels.

The ODEQ prepared a memorandum (ODEQ 2024) that summarizes its findings on the FS (ERM 2023) for LSS. In the memorandum, ODEQ proposed an alternative path forward focused on IRAMs to achieve the following objectives:

1. Expedite the necessary remediation to address high-risk and/or well-defined contamination
2. Decrease potential uncertainty in the FS by resolving data gaps and conducting additional performance monitoring

ODEQ proposed the implementation of IRAM 1 (detailed in Section 1) as an alternative path forward for the following advantages:

- To accelerate cleanup of highest risks (i.e., DNAPL)
- Reduce pesticide co-solvency with chlorobenzene and potentially improve GWET influent characteristics
- Improve near-term source control status in the stranded wedge outside of the groundwater barrier wall
- Reduce the likelihood of a post-record of decision (ROD) administrative change (i.e., Explanation of Significant Differences or ROD Amendment)
- Reduce the scope/magnitude of post-ROD cleanup actions
- Provide a clearer path to Site closure

2. SCOPE OF WORK

This Work Plan describes the field and analytical procedures to be conducted during the PDI to gather sufficient and usable data to evaluate the feasibility of ISS/ISCO for IRAM 1, and the associated design criteria. The boring locations for each phase of investigation are shown on Figure 5.

2.1 IDENTIFYING BORING LOCATIONS AND SUBSURFACE CLEARANCE

Prior to any subsurface investigative activities, ERM will implement subsurface clearance procedures. ERM will review subsurface utility records, as-built drawings, and historical information to select boring locations that are sufficiently far from known existing surface and subsurface utilities. A public utility mark-out will be performed to identify subsurface utilities, and then a private utility locating firm will be subcontracted to clear areas where subsurface work will be performed. Boring locations will be cleared using an air-knife and vacuum truck, per ERM subsurface clearance procedures, before powered drilling equipment is used, where applicable.

Ground surface elevation and geospatial location of the boring locations will be surveyed following drilling completion. The planned boring locations are shown on Figure 5.

2.2 SOIL SAMPLING

ERM proposes to conduct two mobilizations to characterize and delineate the DNAPL plume within the IRAM 1 Treatment Area.

During the first mobilization, ERM plans to perform soil borings with soil sample recovery. The soil sampling procedures are as follows:

- ERM proposes to advance between 20 and 30 borings within the DNAPL zone and outside of the DNAPL zone, as illustrated on Figure 5, using sonic drilling technology. Additional borings may be added while in the field based on field screening results. Specifically, if a boring is located at the previously defined lateral extent of the known DNAPL plume and is found to have DNAPL in the soil, additional borings will be added to refine the limit of the DNAPL plume (i.e., until DNAPL is not encountered).
    - Each boring will be drilled until refusal, or until the Basalt Zone is encountered. Borings that go through the interfaces of the Shallow Intermediate Silt Zone and Intermediate Zone, and the Intermediate Zone and the Deep Zone will be cased off to reduce the potential for contaminant migration. The borings will start with a 10-inch core barrel, reducing to an 8-inch barrel, and finally a 6-inch barrel as each section is cased off.
- Cores will be sampled as described below from ground surface to boring termination.
- Each core will be visually inspected for indications of DNAPL (free product, ganglia, blebs), with the assistance of an oil-soluble dye (Sudan IV or Oil Red O), as necessary. Soil cores will be screened for evidence of VOCs using a photoionization detector (PID).
- Lexan liners may be used during drilling to improve sample integrity, if needed.
- Soil will be logged and photo-documented by a qualified ERM staff geologist and reviewed by an Oregon-Registered Geologist. Soil lithology will be logged and classified according to the

Unified Soil Classification System. Boring lithology will be incorporated into the CSM and reviewed to focus the drilling locations for the second mobilization.

- Soil samples will be submitted for laboratory analysis and will be collected based on visual observations and PID readings. Analysis will include VOCs by United States Environmental Protection Agency (USEPA) Method 5035/8260D. Depending on field and laboratory observation, a modified version of the USEPA 5035 prep method may be used, in which a slightly lower than recommended soil to methanol weight ratio would be collected to prevent methanol saturation with chlorobenzene.
- Soil will be preliminarily categorized as contaminated, some contamination, or no evidence of contamination based on the following criteria:
  - Soil with free product, ganglia, or blebs of DNAPL will be categorized as contaminated.
  - Soil with no visual indications of free product, ganglia, or blebs, but a positive oil soluble dye test or staining, will be categorized as some DNAPL contamination.
  - Soil with no visual indications of free product, ganglia, or blebs; a negative oil soluble dye test; and no staining will be categorized as no evidence of DNAPL contamination.
- Additional soil from the selected analytical sampling intervals, as described above, will be stored onsite in cold storage (preserved at 4 degrees Celsius). Following receipt of analytical results and review of concentrations in correlation with recorded observations, samples will be prepared from the additional soil stored onsite and sent to Loureiro Engineering Associates, Inc., or Evonik Industries for treatability testing using the Synthetic Precipitate Leaching Procedure (SPLP), tank method, and Leaching Environmental Assessment Framework (LEAF) method. Treatability testing is discussed further below in Section 2.4.
- Dakota Technologies, Inc., requests that ERM send samples intended to be representative of the range of potential field conditions, including naturally occurring organic material, DNAPL, residual DNAPL, and not impacted soil, as encountered in the field. These samples will be utilized to evaluate compatibility with the DyeLIF™ system and establish a response curve with respect to concentration. If no free product is encountered during drilling, a sample from the contaminated interval, as defined above, will be sent to Dakota Technologies.
- Representative composite soil samples will be collected for waste characterization.

2.3 DYE-ENHANCED LASER INDUCED FLUORESCENCE LOGGING

During the second mobilization, Dakota Technologies will be contracted (along with their drilling subcontractor) to perform the DyeLIF™ method within the IRAM 1 Treatment Area. The DyeLIF™ method combines a direct-push probe with hydrophobic dye injection. The hydrophobic dye is solvated by the DNAPL and then has a different fluorescent signature than the un-solvated dye. The DyeLIF™ probe detects the fluorescent response of the solvated dye, and this is correlated to a concentration of DNAPL. The logging procedures are as follows:

- ERM proposes to utilize the DyeLIF™ technology at the locations illustrated on Figure 5. These locations will change based on the results from the soil sampling described above in Section 2.2.

- The direct-push probe will be advanced to the bottom of the Shallow Intermediate Silt Zone, or Intermediate Zone, depending on coring results. The step-out decision tree is summarized on Figure 6.
- A Dakota Technologies DyeLIF™ expert will provide ERM with a detailed analysis of the data and a written report to ERM.

The CSM will be updated using DyeLIF™ results, geologic logging, and screening information, along with the analytical results. The CSM will be reviewed to identify residual impacts for targeted remediation. The logs, analytical results, and CSM will be included in the forthcoming Preliminary Design Report. The DyeLIF™ technology is not conducive to using with case-down drilling techniques. Therefore, it can only be used to drill to refusal if a given boring is non-detect for DNAPL. If DNAPL is encountered, the boring will not be advanced through any aquitards that exist below the DNAPL.

2.4 IRAM 1 ISS/ISCO BENCH-SCALE TREATABILITY STUDY

The intent of an ISS remedy is to provide binding of COCs and further encapsulate COCs in a low permeability monolith that will reduce the mobility of COCs in soil (DNAPL) and groundwater (dissolved fraction). In addition, ISS creates a lowered permeability zone that reduces groundwater flux through the monolith and promotes groundwater flow around the monolith. The addition of ISCO to ISS combines the binding and lower permeability effects with destruction via chemical oxidation of the DNAPL. The mass flux reduction related to both physical binding of COCs, coupled with the reduction in hydraulic conductivity combined with the chemical oxidation, is intended to reduce the concentration of COCs at the point of compliance to a concentration that is as low as technically practicable for the Site or low enough to allow for the discontinuance of the GWET and implementation of a more passive remedial approach. Additionally, the mix design for ISS/ISCO may include reagents that promote the oxidation or chemical sorption of COCs, further reducing the mass and/or mobility of COCs in the treatment area.

Soil recovered from the borings during DNAPL plume delineation will be used to perform two parallel treatability studies:

- Soil and groundwater will be collected from outside the DNAPL plume area, but inside the dissolved plume area (i.e., adjacent to the DNAPL plume). These samples will be tested to evaluate the total oxygen demand and soil oxygen demand present in saturated soil from the dissolved plume area. These data will be used to evaluate the type of remedial agent and quantity that may be required by a future IRAM to address COCs in groundwater if IRAM 1 does not fully achieve its objectives.
- The primary treatability study that is the focus of this Work Plan is an ISS/ISCO bench-scale treatability study. The treatability study will evaluate the effectiveness of various mix designs at binding COCs to soil, thus reducing the concentration of COCs in water. The degree of immobilization created by various mix designs will be evaluated using leachability testing.

The goals of the treatability study testing are to:

- Evaluate the reduction in leachability of the COCs from the treated soils for the conditions tested to identify the most effective and economical amendment blends.

- Determine the effects of treatment on soil strength and permeability, with the goal of achieving a reduction in hydraulic conductivity of two to three orders of magnitude, and a minimum soil unconfined compressive strength (UCS) of 50 pounds-force per square inch.
- Determine the degree of swell (i.e., expansion in soil volume) due to the addition of ISS amendments based on bulk density measurements of soil pre- and post-treatment and for cost considerations.

These performance goals are general field measures for ISS/ISCO and are consistent with the July 2011 Interstate Technology and Research Council (ITRC) guidance document "*Development of Performance Specifications for Solidification/Stabilization*" (ITRC 2011).

The ISS/ISCO amendments that will be evaluated during the treatability study are:

- Cement
- Activated carbon
- Cement-activated sodium persulfate

Additionally, trials will be conducted with the ISS/ISCO amendments at various concentrations to evaluate the effect of various amendment rates (or combinations thereof) on the relative reduction of COCs in leachate and thereby as a surrogate for post-mix groundwater conditions.

2.4.1 PHASE 1 TREATABILITY STUDY

The standard SPLP method requires monolithic samples to be broken into pieces of 3/8 inch or less in diameter prior to conducting the leaching procedure. This step would break up the monolith created by the addition of Portland cement, which is not representative of ISS in the field, and creates an unrealistically conservative test case. Therefore, the treatability study will follow the modified SPLP method that will use the same test conditions, solution, duration, and other factors, but does not crush or breakup the sample, keeping the monolith as whole as possible during the test.

For each test condition, the soil will be mixed with the amendments. After the amendments, water, and soil are thoroughly combined, the mixtures for each test condition will be transferred to several replicate molds to supply the laboratories with enough sacrificial samples per analysis per time point. The molds will consist of high-density polyethylene, 2- x 4-inch cylinders, and will be allowed to cure at room temperature until sacrificed for analysis. The number of samples and analyses proposed in Phase 1 are shown in Table 1.

2.4.2 PHASE 2 TREATABILITY STUDY

The reagent(s) that show the best performance from Phase 1 testing will be advanced to leachability testing using the USEPA 1315 LEAF method. The LEAF method provides the release rates of COCs from a monolithic sample in which the predominant water flow is around, not through, the sample. The LEAF method is generally a more accurate representation of the potential for leaching that may occur from a solidified monolithic mass over time compared to the modified SPLP method. The same procedures as the modified SPLP, for creating the monoliths, will be followed during the setup of the LEAF mixtures.

The LEAF method determines the mass-transfer release rate over a series of nine time points for each test condition as the monolith cures over time. At each of the time points, VOCs, semivolatile organic compounds, pesticides, metals, and pH will be measured for each test condition. At the completion of the 63-day study, each of the treatment options will be evaluated for performance and also compared to the control. The number of samples and analyses proposed in Phase 2 depend on the results from Phase 1, but are generally shown in Table 2.

2.5 EQUIPMENT DECONTAMINATION AND WASTE MANAGEMENT

Sampling, drilling, and other field equipment will be decontaminated prior to use and between sample locations. Sampling equipment will be scrubbed with an aqueous solution of laboratory grade detergent, followed by a rinse with tap water, followed by an isopropyl alcohol rinse, followed by a rinse with deionized water.

Soil cuttings and other solids derived from the soil borings will be placed in a lined and covered roll-off box or 55-gallon steel drums for later disposition. Representative composite soil samples will be collected for waste characterization. Each boring will be abandoned immediately upon completion using bentonite grout applied with a tremie pipe. All downhole equipment will be decontaminated on a temporary decontamination pad prior to and after each boring, whereas sampling equipment will be hand washed during sampling activities.

Investigation-derived waste generated during soil sampling activities will be placed in a roll off container and sampled prior to disposal. Decontamination fluids and purge water will be contained in 300-gallon intermediate bulk containers (totes) and then processed in the GWET system. Disposable sampling equipment and used personal protective equipment will be disposed of as non-hazardous solid waste.

2.6 QUALITY ASSURANCE PROJECT PLAN AND HEALTH AND SAFETY PLAN DEVELOPMENT

This Work Plan incorporates previously approved work plans to utilize approved sampling and analysis methods, standard operating procedures, and quality assurance/quality control (QA/QC) procedures. To the extent that there are any inconsistencies to references, the previously approved work plans control in the following order:

1. 2011 Addendum Update to the Quality Assurance Project Plan (QAPP) provided within the *Elf Atochem Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* (Exponent 1998)
2. *Draft – Data Gaps Assessment Work Plan* (ERM 2009), and the addendum to the QAPP to the *Elf Atochem Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* submitted as part of groundwater sampling
3. *Elf Atochem Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* (Exponent 1998)

ERM will develop a Health and Safety Plan (HASP) prior to performing any field activities. The HASP will be prepared to document the procedures to be followed to ensure the safety of the Site workers and surrounding community during the completion of field activities, and to also address the actions to be taken in the event of an emergency situation. The HASP will include information on personnel training, personal protective equipment, anticipated COCs, potential health risks, emergency contact numbers, hospital routes, action levels, and other health and safety related concerns.

2.7 QUALITY ASSURANCE AND QUALITY CONTROL

Field QA/QC samples will be collected in accordance with the QAPP and associated addenda as described in Section 2.6. Trip blanks will be included in each cooler that contains VOC samples. For every 20 samples collected and submitted for analysis, the following QA/QC samples will be collected:

- One field duplicate sample
- One equipment rinsate sample to verify efficacy of decontamination of equipment, collected for every 20 samples
- One matrix spike/matrix spike duplicate

Field notes taken during sampling activities will be recorded in the field logbook. Samples will be immediately labeled following collection, with the required data. Sample data will be entered into the Chain-of-Custody record to ensure proper tracking and control. Analytical samples will be shipped or delivered to the laboratory in sealed containers and accompanied by the Chain-of-Custody record. QA/QC samples will be collected, controlled, and shipped in the same manner as normal field samples.

3. REPORTING

ERM anticipates that the ISS/ISCO bench-scale treatability study results will be available from the laboratory within 16 to 25 weeks of receipt of soil by the laboratory. Results from the DNAPL investigation and treatability testing will be included in a Preliminary Design Report, which will include the analytical data and field observations made during the PDI, as well as the treatability study results. This information will be used to identify the volume of soil proposed for treatment, as well as the mix design consisting of what reagents will be used, and their quantities.

4. SCHEDULE

The estimated schedule is presented below:

- The sampling activities described in Sections 2.3 and 2.4, above, are anticipated to be completed in 20 to 30 onsite working days for the soil sampling program activities and 14 onsite working days for the DyeLIF™. The soil sampling program will be overseen by two ERM field technicians/geologists, while the DyeLIF™ will be overseen by one ERM field technician.
- The Bench-Scale Treatability Study schedule is expected to be completed by year-end 2024, with mobilization for IRAM 1 fieldwork starting in 2025. The schedule for specific tasks within the planned scope of services is anticipated as follows:
    - Test setup following receipt of samples: 1 to 2 weeks
    - Typical time for sample curing: 2 to 4 weeks for UCS/permeability
    - Time to receive sample results: 2 to 3 weeks after submitting samples
    - Review results, plan Phase 2 LEAF, and set up samples: 1 to 2 weeks
    - Typical time for sample curing: 4 weeks for UCS/permeability
    - LEAF testing: 9 weeks
    - Receipt of results: 2 to 3 weeks
    - Final report: 1 to 2 weeks

The proposed project schedule may be affected by outside conditions including, but not limited to:

- Weather
- Surface and subsurface Site conditions
- Contractor availability
- Regulatory approvals
- Utility clearance and location

5. REFERENCES

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TABLES

Table 1
Phase 1 In Situ Stabilization Test Conditions and Analyses
Portland, Oregon

PHASE 1 ISS, ISS/ISCO and ISCO Test Conditions																				
Treatability Sample			Mix Ratios (% weight of dry soil)			UCS	Permeability	Modified SPLP 1312[1] Whole Monolith					Total COCs in Soil					Other		
			PC	C	SP	28 Day	28 Day	VOCs	SVOCs	DDx	Metals	pH	VOCs	SVOCs	DDx	Metals	pH	TOD	SOD	Volumetric Expansion
Contaminated	Baseline [2]						1	1	1	1	1	1	3	3	3	3	3			
	5% PC	5% PC	5%			1	1	1	1	1	1	1								1
		5% PC, 1% C	5%	1%		1	1	1	1	1	1	1								1
		5% PC, 4% C	5%	4%		1	1	1	1	1	1	1								1
		5% PC, 1% SP	5%		1.0%	1	1	1	1	1	1	1								1
		5% PC, 2.5% SP	5%		2.5%	1	1	1	1	1	1	1								1
	10% PC	10% PC	10%			1	1	1	1	1	1	1								1
		10% PC, 1% C	10%	1%		1	1	1	1	1	1	1								1
		10 PC, 4% C	10%	4%		1	1	1	1	1	1	1								1
		10% PC, 1% SP	10%		1.0%	1	1	1	1	1	1	1								1
		10% PC, 2.5% SP	10%		2.5%	1	1	1	1	1	1	1								1
		10% PC, 5% SP	10%		5.0%	1	1	1	1	1	1	1								1
	15% PC	15% PC	15%			1	1	1	1	1	1	1								1
		15% PC, 1% C	15%	1%		1	1	1	1	1	1	1								1
		15% PC, 4% C	15%	4%		1	1	1	1	1	1	1								1
		15% PC, 1% SP	15%		1.0%	1	1	1	1	1	1	1								1
		15% PC, 2.5% SP	15%		2.5%	1	1	1	1	1	1	1								1
		15% PC, 5% SP	15%		5.0%	1	1	1	1	1	1	1								1
	ISCO	Baseline [2]																1	1	
		Alk-SP 1%											3	3	3	3	3			
		Alk-SP 2%											3	3	3	3	3			
Some DNAPL Contamination	Baseline [2]						1	1	1	1	1	1	3	3	3	3	3			
	5% PC	5% PC	5%			1	1	1	1	1	1	1								1
		5% PC, 1% C	5%	1%		1	1	1	1	1	1	1								1
		5% PC, 4% C	5%	4%		1	1	1	1	1	1	1								1
		5% PC, 1% SP	5%		1.0%	1	1	1	1	1	1	1								1
		5% PC, 2.5% SP	5%		2.5%	1	1	1	1	1	1	1								1
	7.5% PC	7.5% PC	7.5%			1	1	1	1	1	1	1								1
		7.5% PC, 1% C	7.5%	1%		1	1	1	1	1	1	1								1
		7.5% PC, 4% C	7.5%	4%		1	1	1	1	1	1	1								1
		7.5% PC, 1% SP	7.5%		1.0%	1	1	1	1	1	1	1								1
		7.5% PC, 2.5% SP	7.5%		2.5%	1	1	1	1	1	1	1								1
		7.5% PC, 5% SP	7.5%		5.0%	1	1	1	1	1	1	1								1
	10% PC	10% PC	10%			1	1	1	1	1	1	1								1
		10% PC, 1% C	10%	1%		1	1	1	1	1	1	1								1
		10 PC, 4% C	10%	4%		1	1	1	1	1	1	1								1
		10% PC, 1% SP	10%		1.0%	1	1	1	1	1	1	1								1
		10% PC, 2.5% SP	10%		2.5%	1	1	1	1	1	1	1								1
		10% PC, 5% SP	10%		5.0%	1	1	1	1	1	1	1								1
	ISCO	Baseline [2]																1	1	
		Alk-SP 1%											3	3	3	3	3			
		Alk-SP 2%											3	3	3	3	3			
No Evidence of DNAPL Contamination (i.e. outside of DNAPL area, within dissolved plume)	ISCO	Baseline [2]											3	3	3	3	3	1	1	
		Alk-SP 1%											3	3	3	3	3			
		Alk-SP 2%											3	3	3	3	3			
Total Number of Tests Phase 1:						34	36	36	36	36	36	36	27	27	27	27	27	3	3	34

Notes:
[1] Synthetic Precipitation Leaching Procedure, modified to keep the monolith whole instead of crushing
[2] Baseline sample submitted prior to test setup to confirm soil is impacted with typical levels of COCs detected at the site.
Alk-SP = alkaline-activated sodium persulfate, activate with sodium hydroxide according to supplier recommendations
C = carbon
COC = contaminant of concern
DDx = 4,4'-DDT, -DDE, -DDD
Metals = total recoverable metals
PC = Portland cement
SOD = Soil Oxidant Demand, assumes clean or minimally impacted soil
SP = sodium persulfate
SVOCs = semi-volatile organic compounds
TOD = Total Oxidant Demand, assumes impacted soil
UCS = unconfined compressive strength
VOCs = volatile organic compounds
x% = weight of reagent to weight of soil

Test Name	Method Reference
Unconfined Compressive Strength	ASTM D2166
Permeability Testing	ASTM D5084
Modified SPLP	EPA Method 1312, modified to keep the monolith whole

Table 2
Phase 2 In Situ Stabilization Test Conditions and Analyses
Portland, Oregon

PHASE 2 Test Conditions													
Treatability (Monolith leachability) testing		**Mix Ratios (% weight of dry soil) To Be Determined by Phase 1**			**UCS**		**Permeability**		**LEAF 1315 [1]**				
		PC	**C**	**SP**	**28 Day**	**56 Day**	**28 Day**	**56 Day**	**VOCs**	**SVOCs**	**DDx**	**Metals**	**pH**
Contaminated	Control								9	9	9	9	9
	Condition #1				1	1	1	1	9	9	9	9	9
	Condition #2				1	1	1	1	9	9	9	9	9
	Condition #3				1	1	1	1	9	9	9	9	9
	Optional Condition #4				1	1	1	1	9	9	9	9	9
	Optional Condition #5				1	1	1	1	9	9	9	9	9
Some DNAPL Contamination	Control								9	9	9	9	9
	Condition #1				1	1	1	1	9	9	9	9	9
	Condition #2				1	1	1	1	9	9	9	9	9
	Condition #3				1	1	1	1	9	9	9	9	9
	Optional Condition #4				1	1	1	1	9	9	9	9	9
	Optional Condition #5				1	1	1	1	9	9	9	9	9
Total Phase 2:					10	10	10	10	108	108	108	108	108

Notes:
[1] The LEAF 1315 testing consists of 9 discrete eluate changes at 9 time points of 0.08, 1, 2, 7, 14, 28, 42, 49, and 63 days. The control consists of upgradient, uncontaminated groundwater in contact with untreated, unconsolidated soil.

μg/L = micrograms per liter
COC = contaminants of concern
C = carbon
PC = Portland cement
SP = sodium persulfate
UCS = unconfined compressive strength
VOCs = volatile organic compounds
SVOCs = semi-volatile organic compounds
DDx = 4,4'-DDT, -DDE, -DDD
Metals = total recoverable metals
Condition = results of Phase 1 will inform the type and quantity of amendments tried in Phase 2

Test Name	Method Reference
Unconfined Compressive Strength	ASTM D2166
Permeability Testing	ASTM D5084
LEAF	EPA Method 1315

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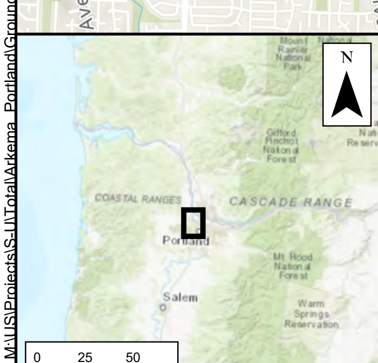
FIGURES



Legend

— Parcel and Property Boundaries

N

0 1 2
Miles

Figure 1
Site Location
Arkema Inc.
Portland, Oregon

ERM

Source: Esri - World Topoographic Map; NAD 1983 StatePlane Oregon North FIPS 3601 Feet Intl

FILE: M:\US\Projects\S-U\Total\Arkema_Portland\Groundwater Source Control\maps\SS PDI Workplan\SS PDI Workplan.aprx | REVISED: 04/25/2024 | SCALE: 1:63,360 when printed at 11x17 | DRAWN BY: GIS

Legend

- Parcel and Property Boundaries
- Lot Boundaries
- Acid Plant Area and Chlorate Plant Area Boundaries

Note:
A number of the buildings and structures noted on this diagram have been demolished and/or removed.

Figure 2
Historical Site Layout
Arkema Inc.
Portland, Oregon

ERM

M:\US\Projects\S-U\Total\Arkema_Portland\Groundwater Source Control\Maps\Final Design Report 2022\Figure 1-2 Historical Site Layout.mxd, REVISED: 07/24/2023, SCALE: 1:2,400 when printed at 11x17, DRAWN BY: Jake Sullivan and Jimmy Holcomb

Source: City of Portland Aerial Imagery, Flow 7/2018 at 6in per pixel; NAD 1983 HARN StatePlane Oregon North FIPS 3601 Feet Intl

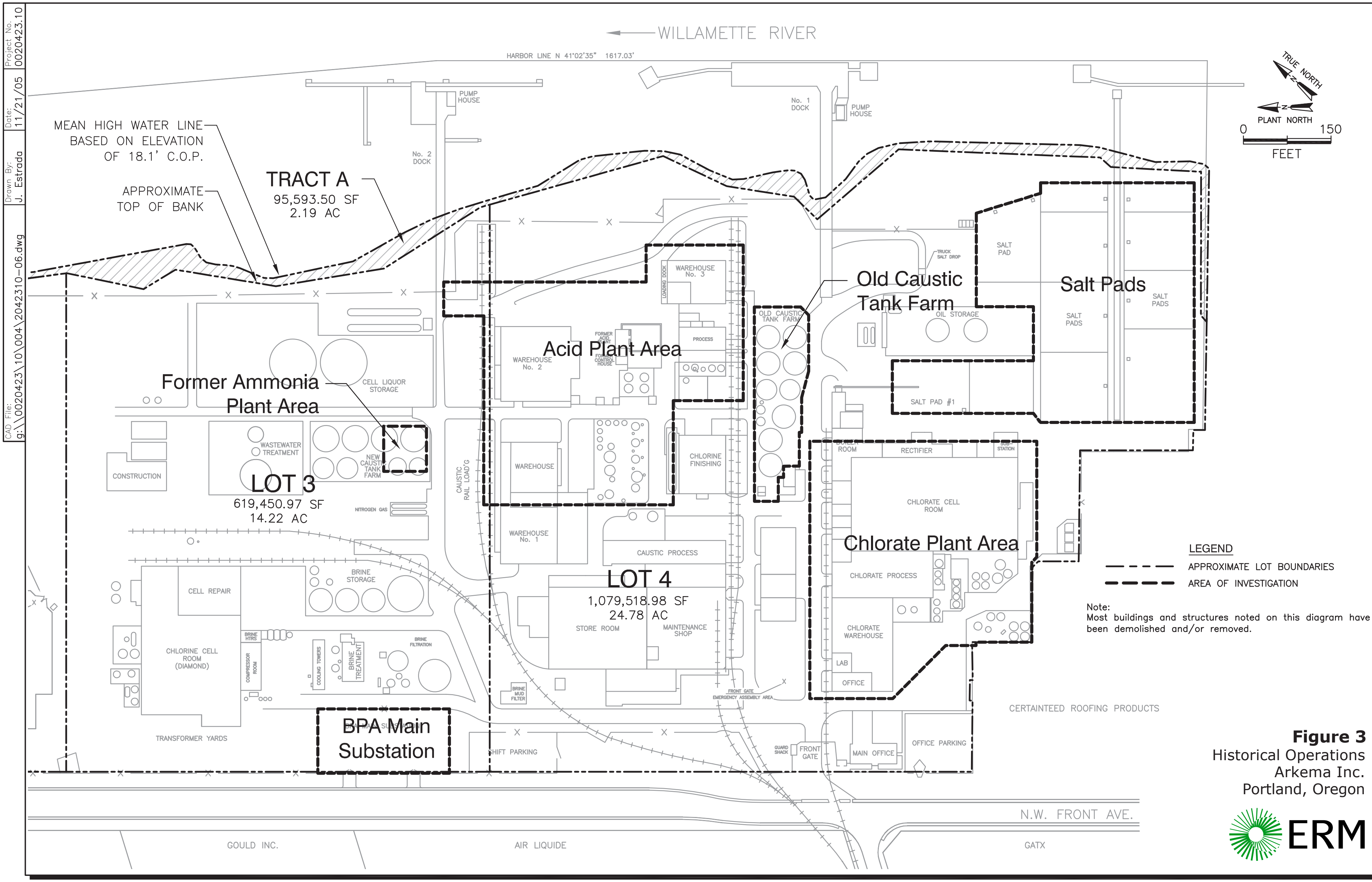
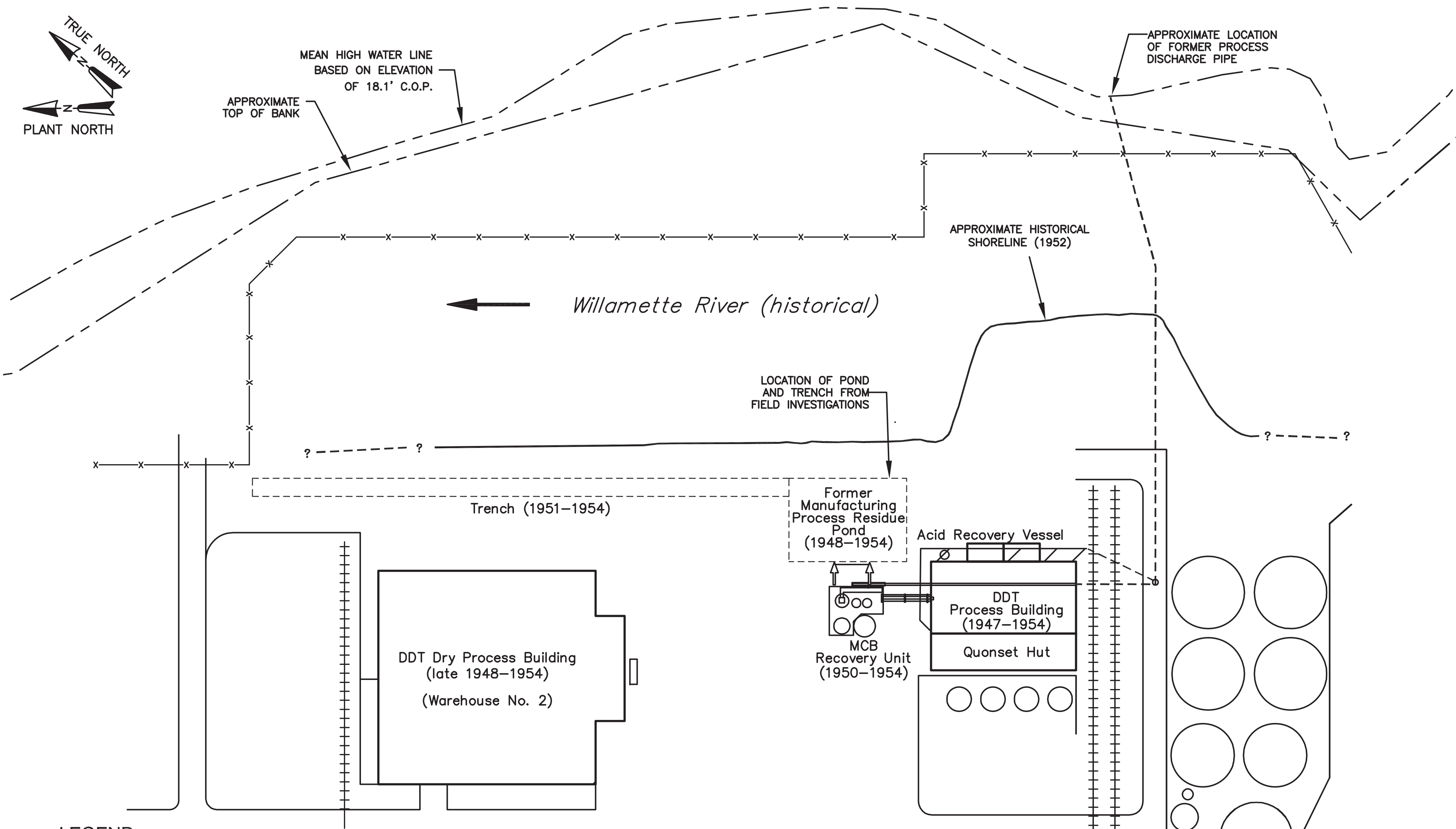


Figure 3
Historical Operations
Arkema Inc.
Portland, Oregon

CAD File:	Drawn By:	Date:	Project No.
g:\\0020423\10\002042310-07.dwg	J. Estrada	11/21/05	0020423.10



LEGEND

--- Sewer Pipelines (approximate)

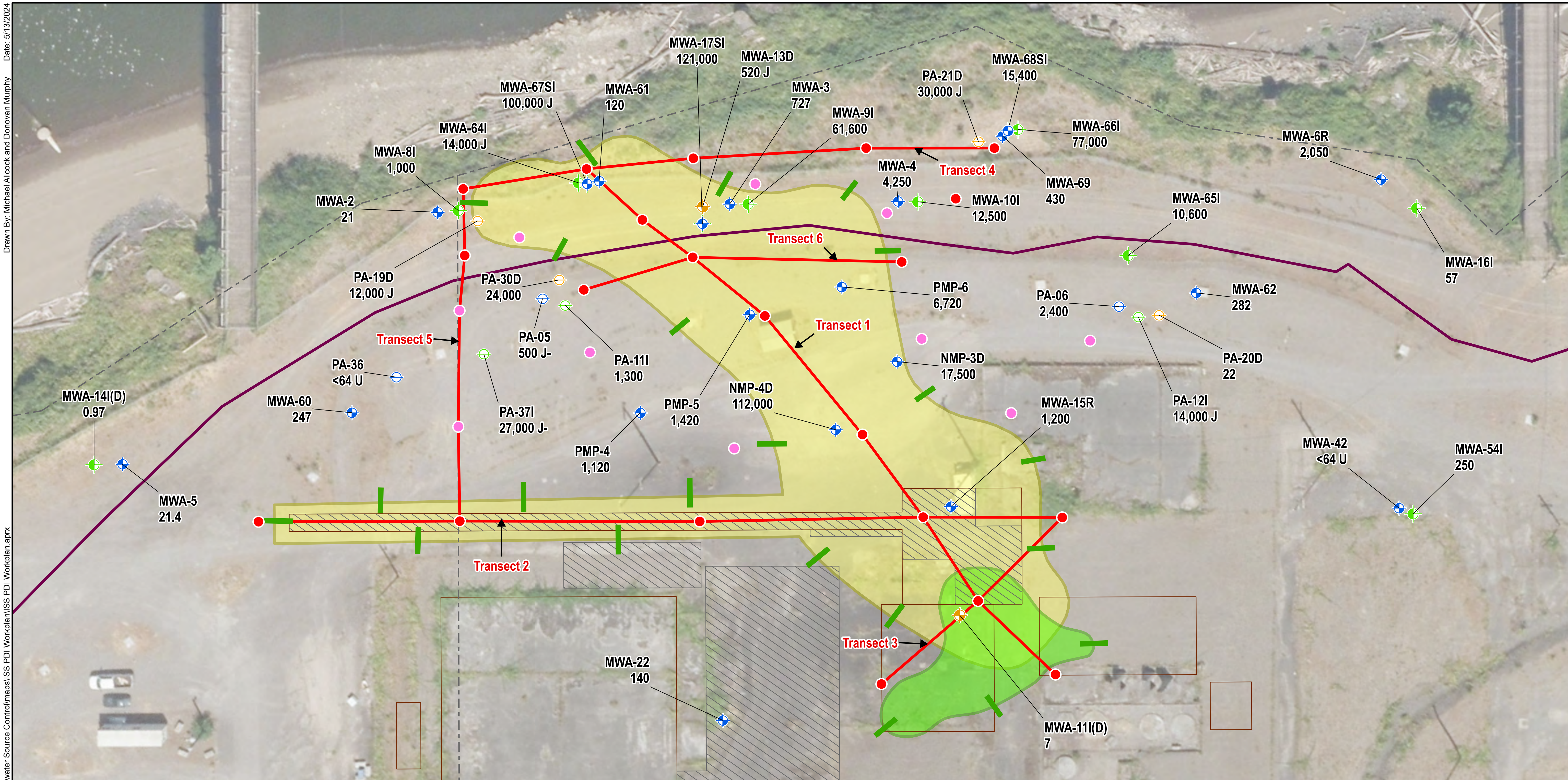
⇦ Discharge to Pond

Notes:
1. All dates are approximate.
2. Most buildings and structures noted on this diagram have been demolished and/or removed.

0 40 80
Approx. Scale (feet)

Figure 4
Historical DDT Manufacturing Operations (1947-1954)
Arkema Inc.
Portland, Oregon

ERM



Legend

- Proposed Primary Boring Location
- Proposed Secondary Boring Location
- Proposed DyeLIF Transect Location
- Proposed Transect
- Shallow Zone Monitoring Well
- Shallow Zone Piezometer
- Intermediate Zone Monitoring Well
- Intermediate Zone Piezometer
- Deep Zone Monitoring Well
- Deep Zone Piezometer
- Barrier Wall Alignment
- Parcel and Property Boundaries
- Shallow Aquifer Zone DNAPL
- Vadose Soil Zone DNAPL (5-10 ft bgs)
- Excavated Area

Note:
Most recent chlorobenzene results are displayed at each well location in micrograms per liter (µg/L).

N

0 25 50 100
Feet

Figure 5
Proposed Boring and Transect Locations
ISS PDI Workplan
Arkema Inc.
Portland, Oregon

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Drawn By: Michael Allcock and Donovan Murphy Date: 5/13/2024

File: M:\US\Projects\S-U\Total\Arkema_Portland\Groundwater Source Control\maps\ISS PDI Workplan\ISS PDI Workplan.aprx

Imagery Source: City of Portland, 2018; NAD 1983 HARN StatePlane Oregon North FIPS 3601 Feet Intl

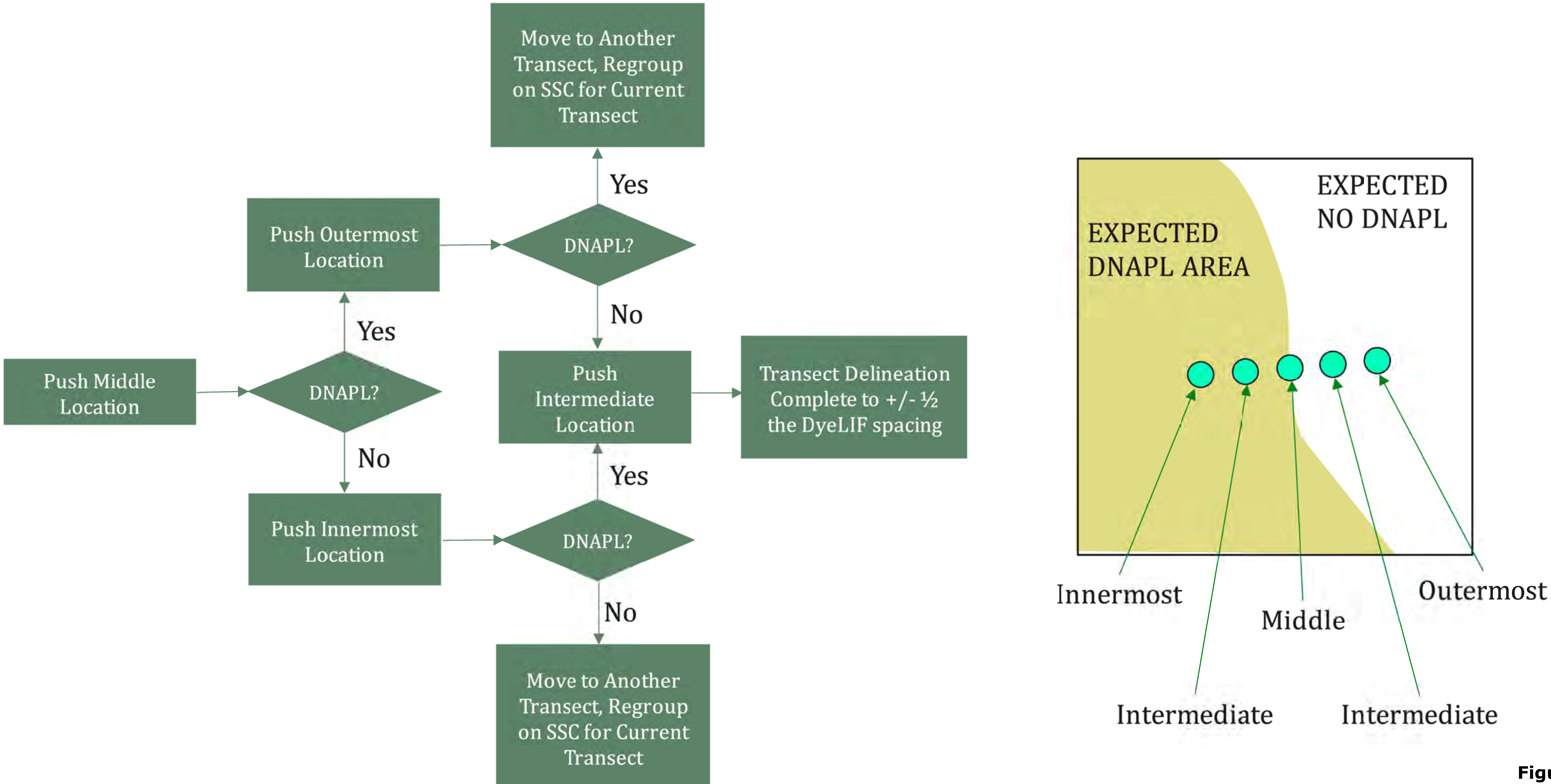

Figure 6
Proposed DyeLIF Decision Tree
ISS PDI Workplan
Arkema Inc.
Portland, Oregon

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File: M:\US\Projects\S-U\Total\Arkema_Portland\Groundwater Source Control\maps\ISS PDI Workplan\ISS PDI Workplan.aprx   Drawn By: Michael Allcock and Donovan Murphy   Date: 5/13/2024

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