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White Paper on Addressing Human Health and Ecological Risks from Exposures to Impacted Soils in OU2 and OU4

This white paper presents an overview of the proposed approach by the Greenfield Environmental Multistate Trust LLC (Multistate Trust) for evaluating human health and ecological risks from exposures to creosote wood treating facilities contaminants, specifically polycyclic aromatic hydrocarbons (PAHs) and dioxins/furans in soils in Operable Units 2 and 4 (OU2 and OU4) of the Kerr-McGee Chemical Corp – Navassa Superfund Site (the Site) (Figure 1). This document has been revised to incorporate input received from the U.S. Environmental Protection Agency (EPA) and North Carolina Department of Environmental Quality (NCDEQ) and documents the agreed-upon framework for addressing risks associated with impacted soils in OU2 and OU4.

1 Anticipated Future Land Use

Although a final determination of the future land use has not been made for OU2 or OU4, the Town of Navassa (Town) has expressed a preference for a mix of land uses, with the majority of the Site designated for some form of human use. A potential exception to this is the southern portion of OU4 that is below the 100-year floodplain and is unlikely to be developed for human use. Figure 2 presents a conceptual site redevelopment plan for the Site. This plan is conceptual and does not represent the final redevelopment plan for the Site but is provided as an example of how the property may be used in the future. The conceptual plan includes a range of land uses, including industrial, commercial, and recreational.

The specific recreational use has not been identified. The Town of Navassa has identified development of sports fields or nature trails as potential recreational uses. If nature trails were developed, all or parts of OU2 and/or OU4 could remain as a largely undeveloped, natural area.

The human health and ecological risk evaluations will consider a range of potential land uses, including industrial/commercial, recreational with minimal development (e.g., nature trails), and recreational with development (e.g., sports fields). In addition, the human health risk evaluation will consider residential use to determine if there is a risk to a potential future resident, should all or a portion of OU2 or OU4 be developed for residential use and/or to establish if there is a need for institutional controls to prevent residential use. Each of the potential land uses was considered in the development of the

conceptual site exposure models (CSEMs) and identification of potential receptors for the human health and ecological risk evaluations, as discussed below.

2 Human Health Risk Conceptual Site Model

Human health risks for the Site were evaluated in the human health risk assessment (HHRA) and HHRA Addendum (EarthCon 2019a, b), which have been approved by EPA and NCDEQ. OU2 includes the Treated Wood Storage Area and part of the Untreated Wood Storage Area (Figure 1), which were exposure areas in the 2019 HHRA. OU4, as currently defined, includes all the Process Area, all the Pond Area, and part of the Untreated Wood Storage Area. These areas were also exposure areas used in the 2019 HHRA.

As summarized in Table 3-2 from the 2019 HHRA, unacceptable risks were estimated for construction workers in the Pond and Process Areas, and supporting tables show PAH contamination is responsible for most of the risk. However, additional data collection was and is needed to support risk management decisions and to evaluate potential risks associated with dioxins and furans in soils. This white paper describes the Multistate Trust's approach to evaluating human health risks in OU2 and OU4 based on the updated data set. The approach incorporates the framework documented in the 2019 HHRA/HHRA Addendum, as well as discussions between the Multistate Trust, EPA, and NCDEQ.

2.1 Conceptual Site Exposure Model

The 2019 HHRA and HHRA Addendum included human health CSEMs for the Untreated and Treated Wood Storage Areas and the Pond and Process Areas. These CSEMs have been updated based on the December 11, 2020, and January 8, 2021, discussions and direction received from EPA and NCDEQ. The CSEMs are provided as Figures 3 and 4 and have updates to include the following two additional potential receptors: site visitors/trail walkers and youth sports players.

2.2 Potential Receptors and Exposure Parameters

Tables 1a and 1b summarize the potential receptors and assumed exposure area sizes for the range of potential land uses that have been identified for OU2 and OU4, respectively. Table 2 summarizes the exposure parameters used for receptors identified in the approved 2019 HHRA and HHRA Addendum for OU2 and OU4 soils.[1] In addition, Table 2 summarizes exposure parameters for the newly identified potential receptors: site visitors/

[1] Although the HHRA did not explicitly evaluate a recreational receptor, the HHRA Addendum includes an evaluation of a teenage trespasser receptor for OU2 and states: "The exposure assumptions used to evaluate a trespasser are protective of a recreator; therefore, risk and hazard to the recreator were not quantified separately in the HHRA."

trail walkers and youth sports players, which were developed collaboratively by EPA, NCDEQ, and the Multistate Trust. The exposure parameters in Table 2 will be used to evaluate soils data for OU2 and OU4 to determine if there is an unacceptable risk and an associated need for remediation. The framework for evaluating risk in OU2 and OU4 is described in Section 4, below.

3 Ecological Risk Conceptual Site Model

The ecological risk assessments (ERAs) for OU2 and OU4 soils will build on the approach used by EPA for OU1 (USEPA 2020). Ecological CSEMs for OU2 and OU4 are provided as Figures 5 through 8. As summarized in Tables 1c and 1d, the OU2 and OU4 ERAs will consider songbirds, mammals, and soil invertebrates as potential ecological receptors depending on the land use scenario being evaluated.

It is anticipated that all of OU2 and the portion of OU4 that is above the floodplain will be redeveloped for some form of human use, including residential, commercial/industrial, and/or recreational use. Except for the development of recreational nature trails (discussed below), these uses would limit the extent of ecological habitat/function. Therefore, when evaluating residential, commercial/industrial, and/or recreational (sports field) land uses in OU2 and the OU4 area that is outside of the floodplain, the ERAs will not address resident ecological function (e.g., soil invertebrates, mammals) and will focus on risks to animals that may be part of offsite populations and come to forage on the Site ("attractive nuisance" type risks). Consistent with OU1, songbirds (American robin and American woodcock) are considered the most at-risk receptor from this type of exposure scenario.

If all or a portion of OU2 and/or the area of OU4 that is outside of the floodplain are designated for use as a natural trail system, these areas may remain in a natural state and support a broader ecological habitat/function. Therefore, the OU2 and OU4 ERAs will include an evaluation of receptors indicative of ecological function (including soil invertebrates and mammals) in addition to songbirds when evaluating the nature trail land use scenario (Tables 1c and 1d). Finally, because the portion of OU4 that is within the floodplain is unlikely to be developed in the future beyond construction of nature trails for hiking and/or to access the marsh shoreline (e.g., for a kayak launch), the OU4 ERA for this area will include an evaluation of songbirds, mammals, and soil invertebrates.

The rationale for selection of the avian and mammal species includes:

- These species are omnivorous, but their diets can be dominated by the ingestion of soil invertebrates, so they have high exposure to contaminants from their diets.
- Each species forages within the soil and soil litter and can have incidental ingestion of soil via foraging methods that is greater than other species.

- Exposure parameters for each species are identified by EPA (USEPA 2020) and agreed upon by NCDEQ.
- There is habitat present in OU2 and OU4 for each of these species.
- American robins and short-tailed shrews have relatively small home ranges.

4 Risk Evaluation

The following presents the approach that will be taken to quantify human health and ecological risks due to exposure to impacted soils in OU2 and OU4 and to determine the areas requiring remediation.

4.1 OU2

The approach that will be taken to quantify human health and ecological risks due to exposure to impacted soils in OU2 and to determine the areas requiring remediation is described below.

4.1.1 Data

EPA, NCDEQ, and the Multistate Trust have designed and implemented data collection in OU2 sufficient to evaluate and manage risks. Specifically, soils have been and are being sampled on each 0.25-acre parcel to support assessment of human health risks to a future resident. The resulting data set is adequate to evaluate human health and ecological risks for any land use that may be determined for OU2.

4.1.2 Human Health Risk Assessment

The following steps will be taken to evaluate human health risks at OU2.

- ***Selection of representative data.*** A representative concentration will be selected for each chemical of interest (COI) to be carried forward in the screening for constituent of potential concern (COPC) and for the derivation of exposure point concentrations (EPCs). The composite sample will be selected as the representative data where available. For parcels with no composite samples, and less than 8 discrete samples collected, the maximum of the concentrations measured in the discrete samples will be selected as the representative concentration for the parcel. This will result in one representative concentration per constituent for each 0.25-acre parcel (Figure 9).
- ***COPC screening.*** To select surface soil COPCs, the maximum concentrations of detected chemicals across the OU2 representative data set will be compared to EPA's regional screening levels (RSLs) for residential soils (USEPA 2021). The RSLs are based on a noncancer hazard quotient (HQ) of 0.1 and a cancer risk level of 1×10^{-6}. Consistent with the 2019 HHRA, the RSL for pyrene will be selected as a

surrogate for the following PAHs for which no RSL is available: acenaphthylene, benzo[*g*,*h*,*i*]perylene, and phenanthrene. Constituents with maximum representative concentrations exceeding the RSLs at the above-defined risk levels will be retained as COPCs and evaluated quantitatively in the risk assessment.

- ***Identification of exposure areas.*** OU2 was divided into exposure units of different sizes dependent on the receptor being evaluated as follows:
  - Residents: exposure areas (parcels) no greater than 0.25 acre created by Thiessen polygon methodology.
  - Commercial/industrial workers, construction workers, trespassers, and recreational youth sports players: exposure areas no greater than 2 acres.
  - Site visitor/trail walkers: exposure areas no greater than 6 acres.

  The exposure areas no greater than 2 acres and no greater than 6 acres were developed as areas of contiguous parcels with the highest concentrations of benzo[*a*]pyrene (BaP) toxic equivalency (TEQ) and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) TEQ. These exposure areas were presented to EPA and NCDEQ in February 2021 and approved. They are displayed in Figures 10 and 11.
- ***Calculation of exposure point concentration (EPCs)***. An EPC for each COPC in each exposure area will be calculated as follows:
  - Residential exposure areas (i.e., parcels no greater than 0.25 acre)—the data from the representative sample identified for each parcel (described above) will be selected as the EPCs.
  - Exposure areas no greater than 2 acres and no greater than 6 acres—surface weighted average concentrations (SWACs) will be calculated for each COPC. This approach was agreed upon with EPA and NCDEQ on May 12, 2021.
- ***Calculation of excess lifetime cancer risk (ELCR) and noncancer hazard indices (HIs).*** Cumulative ELCRs and noncancer HIs will be calculated for each of the identified receptors consistent with EPA guidance for risk assessment (USEPA 1989). To evaluate cumulative noncancer effects, HQs will be summed for all COPCs and across all relevant exposure pathways to determine a noncancer HI. If the total HI for a particular receptor exceeds 1.0 for all COPCs combined and across all exposure pathways, consideration will be given as to whether the COPCs affect the same target organ or endpoint following EPA guidance (USEPA 1989). At the direction of NCDEQ, and consistent with EPA guidance (USEPA 2018), ELCRs and HIs in the HHRA will be presented to two significant figures. The exposure parameters outlined in Table 2 will be used. Site-specific volatilization factors (VFs) and particulate emission factors (PEFs) were derived. The VFs and PEFs were approved by EPA and NCDEQ by email on May 27, 2021. The approved VFs and PEFs are presented in Attachment 1. Toxicity values for each COPC will be selected

following the EPA recommended hierarchy (USEPA 2003).

In line with EPA Region 4 guidance (USEPA 2018), constituents of concern (COCs) will be identified for receptors and exposure areas that either 1) exceed a 1.0×10^{-4} cumulative site cancer risk, or 2) exceed an endpoint-specific noncancer HI of 1.0. COCs will be identified as those COPCs that contribute 1.0×10^{-6} or greater cancer risk to a 1.0×10^{-4} cumulative ELCR or, 0.10 or greater noncancer hazard to a noncancer HI of 1.0.

Site-specific remediation goals (SSRGs) will be calculated using the parameters identified and applied in the forward calculation of risks and hazards for the relevant receptors. Following USEPA (2018) Region 4 guidance, SSRGs will be established based on a range of potential cleanup levels. The cancer risk levels for carcinogenic COCs are 1.0×10^{-6}, 1.0×10^{-5}, and 1.0×10^{-4}. SSRGs based on noncancer COCs will be established at target levels of 0.10, 1.0, and 3.0. SSRGs will be presented to two significant figures, in line with NCDEQ's requests on the forward calculation of cancer risks and noncancer hazards. Applicable or relevant and appropriate requirements, appropriate groundwater protection levels, state guidance concentrations, and any other cleanup numbers that may pertain, as provided by EPA and NCDEQ, will also be provided alongside the SSRGs.

4.1.3 Ecological Risk Assessment

The OU2 ERA will be based on consideration of risks to wildlife estimated using HQs:

- For soil invertebrates, HQs will be calculated for PAHs based on a comparison of OU2 high molecular weight (HMW) and low molecular weight (LMW) PAH soil concentrations to the EPA PAH ecological soil screening levels (EcoSSLs) for soil invertebrates.[2] HQs will be calculated as the ratio of concentration in each less than 0.25-acre parcel (using the representative concentration established for the parcel as described below) to the EPA PAH EcoSSLs. The EPA PAH EcoSSLs for soil invertebrates used to calculate HQs are based on studies including 10% reduction of reproduction and growth. This means that HQs exceeding 1 may indicate a 10% reduction of reproduction and growth.
- For songbirds and mammals, the HQ will be calculated as the ratio of concentration exposures estimated from a food web model to the lowest-observed-adverse-effect level (LOAEL) toxicity reference values (TRVs) protective of birds and mammals. LOAEL HQs will be calculated for each receptor for the HMW and LMW PAHs and for bird and mammal polychlorinated dibenzo-*p*-dioxin/furan (PCDD/F) TEQs. A food web model will be developed to estimate exposure based on species-specific

[2] Soil invertebrate's exposure to polychlorinated dibenzo-*p*-dioxins/furans (PCDD/Fs) was not considered because invertebrates lack the AHR-1 aryl hydrocarbon (AhR) receptor where PCDD/F binding occurs and, therefore, are not sensitive to PCDD/F toxicity.

ecological exposure parameters and estimated total daily intake calculations. EPA Region 4 TRVs will be used as estimates of safe levels for the HQ calculation.

Exposure parameters to be used in the food web model are presented in Table 3. Exposure areas are 15.6 acres (all of OU2) for large home range species and 2 acres for small home range species (Table 1c). EPCs will be estimated based on the available OU2 data set, which includes results for both composite soil samples and for discrete samples collected from individual parcels. For the purposes of the ERA, a representative soil concentration will be established for each parcel as follows:

- Where available, composite sample results will be used.
- For parcels with no composite sample data for a given analyte, the upper confidence limit (UCL) concentrations, as calculated using EPA's ProUCL software (Version 5.1.00), will be used unless the UCL exceeds the maximum concentration measured in the parcel, in which case the maximum concentration will be used.

EPCs will be calculated as SWACs based on the exposure area for each species. The SWAC will be based on the representative concentration established for each parcel and will be calculated using the following formula:

$$SWAC = \frac{(Area_{Parcel\,1} \times Concentration_{Parcel\,1}) + (Area_{Parcel\,2} \times Concentration_{Parcel\,2}) + \ldots}{Area_{Parcel\,1} + Area_{Parcel\,2} + \ldots}$$

- **Large home range bird and mammal receptors (American woodcock and raccoon):** To address ecological risk to large home range birds and mammals, PAH and PCDD/F TEQ exposure concentrations for soil will be based on the SWACs for all OU2. The OU2 ERA will include two exposures considerations woodcock and raccoon, which have natural home ranges larger than the spatial scale of OU2. The first exposure consideration will assume that these species live exclusively at OU2 (i.e., area use factor [AUF] = 1). The second exposure consideration will be based on the estimated home range of the woodcock and raccoon relative to the size of OU2 (i.e., the animals move into and out of OU2 as they naturally move around their home ranges) (Table 3).
- **Small home range bird and mammal receptors (American robin and shrew):** To address ecological risk to small home range birds and mammals, a 2-acre exposure area will be used, and an EPC will be calculated based on the SWAC for 2-acre circular area centered on the parcel(s) with the highest concentrations of PAHs and PCDD/F TEQ in surface soil. The food web model will assume that small home range birds and mammals live only within this 2-acre area.

The food web model for birds and mammals will use dietary exposure scenarios that range from high exposure diet scenarios (i.e., diets that would lead to greater exposure than

expected under true Site conditions) to diet scenarios that more realistically represent the mix of food sources that the receptor is likely to eat from OU2. The diet scenarios to be considered are composed of the following:

American Robin[3]

- Scenario 1: A diet consisting of solely belowground invertebrates (i.e., earthworms), which reflects the high exposure diet for the robin
- Scenario 2: A diet split 50/50 between plants and belowground invertebrates
- Scenario 3: A diet consisting of 50% aboveground and 50% belowground invertebrates
- Scenario 4: A diet consisting of 30% plants, 35% aboveground invertebrates, and 35% belowground invertebrates, which is a more realistic representation of the robin's diet at OU2

American Woodcock

- Scenario 1: A diet consisting of solely belowground invertebrates (i.e., earthworms), which reflects the high exposure diet for the woodcock
- Scenario 2: A diet consisting of 50% aboveground and 50% belowground invertebrates, which is a more realistic representation of the woodcock's diet at OU2

Raccoon

- Scenario 1: 20% plants and 80% belowground invertebrates (i.e., earthworms), which reflects the high exposure diet
- Scenario 2: 20% plants, 40% aboveground invertebrates, and 40% belowground invertebrates, which is a more realistic representation of the raccoon's diet at OU2

Shrew

- Scenario 1: 100% belowground invertebrates, (i.e., earthworms), which reflects the high exposure diet

[3] Four dietary scenarios will be used for the American robin and two dietary scenarios are used for each of the other ecological receptors (woodcock, raccoon, and shrew). The diets for the robin include ingestion of invertebrates and plants. As indicated in the OU1 Semi-Screening ERA, "plant material is expected to contain very little PAH, as plants have in general not been observed to accumulate lipophilic compounds such as PAHs into their fruits to an appreciable extent. It is expected that incorporation of plant material into the diet of robins would likely serve to decrease the estimated PAH dose the birds are receiving, and thereby lower the estimated risks." Therefore, the OU2 ERA will include plant materials as part of the food web model.

- Scenario 2: 50% belowground invertebrates and 50% aboveground invertebrates, which is a more realistic representation of the shrew's diet at OU2.

The food web model for birds and mammals will consider uptake from soil to dietary prey items based on the site-specific uptake factors derived from the June 2020 soil and soil invertebrate PAH and PCDD/F study. The total daily intakes estimated from the food web model will be compared to the EPA TRVs to calculate HQs for the range of exposure scenarios to be considered in the OU2 ERA (i.e., diets, AUFs, land uses). An LOAEL HQ > 1 would indicate potentially unacceptable risks; however, as was determined for OU1, a higher LOAEL HQ (e.g., 2–4) may be acceptable given 1) the uncertainty in the risk estimates that, if accounted for, would tend to lower the risk, and 2) the knowledge that all or a large portion of OU2 and OU4 will likely be redeveloped in the future.

If the ERA concludes there is an unacceptable ecological risk for OU2, the Feasibility Study will include consideration of the future condition following any remediation determined necessary to address unacceptable human health risk (i.e., data from areas of impacted soils that will be remediated to address human health will be excluded from the calculations, as appropriate) to determine what, if any, additional remediation is required to address ecological risk.[4]

4.1.4 Subsurface Soil Sampling

North Carolina's Guidelines for Assessment and Cleanup of Contaminated Sites states:

- "Even if the site property is, and/or will be, designated as industrial-use only, the extent of contamination must be delineated to the unrestricted-use goals to identify where land use controls must be placed."
- "The unrestricted-use remediation goals referenced in this document (See Chapter 3.0) must be used as delineation endpoints for soil, groundwater, and surface water during the remedial investigation."

NCDEQ has previously indicated that there are sufficient data to achieve these objectives for PAHs. However, the vertical extent of dioxins/furans contamination has not been established. To achieve this objective, sampling is ongoing in OU2 to delineate the vertical extent of TCDD TEQ in the 0.25-acre parcels where TCDD TEQ concentrations in surface soils (0–1 ft below ground surface [bgs]) exceed the 50 parts per trillion (ppt) criteria established for unrestricted (residential) use. The following summarizes the sampling

[4] ERA analyses conducted to date suggest there is an unacceptable ecological risk due to HMW PAHs in soils and that the highest concentrations are limited to a small number of parcels—several of which will be remediated to address human health risks. Remediation to address human health risks would result in a reduction of the ecological HQs.

approach that was approved by NCDEQ on February 12, 2021 and EPA on February 16, 2021.

As summarized below, there are seven parcels that have surface soil TCDD TEQ concentrations that exceed 50 ppt (Figure 12). All seven of the parcels have a composite sample, and three of the seven parcels also have discrete samples.

Parcel	Composite Sample > 50 ppt	Discrete Samples > 50 ppt
CS-56	Yes	3 of 5 samples
SB-148	Yes	NA
RISB05	Yes	NA
SS-115	Yes	NA
SB-136	Yes	NA
CS-66	Yes	0 of 6 Samples
CS-68	Yes	0 of 6 Samples

The following are the soil sampling procedures:

Parcels SB-148, RISB05, SS-115, SB-136, CS-66, and CS-68

- Samples were collected from 1–2 ft bgs and 2–3 ft bgs from the locations where the five increments were collected to create the five-point composite surface soil sample from the parcel.
- The 1–2 ft bgs samples were analyzed for TCDD TEQ and the 2–3 ft bgs samples will be archived.
- If any of the 1–2 ft bgs samples exceeds 50 ppt TCDD TEQ, the associated 2–3 ft bgs sample will be analyzed for TCDD TEQ.

Parcel CS-56

- Discrete samples were collected from 1–2 ft bgs and 2–3 ft bgs at each of the three discrete sample locations where surface soils were >50 ppt TCDD TEQ.
- The 1–2 ft bgs samples were analyzed for TCDD TEQ and the 2–3 ft bgs samples will be archived.
- If any of the 1–2 ft bgs samples exceeds 50 ppt TCDD TEQ, the associated 2–3 ft bgs sample will be analyzed for TCDD TEQ.

The OU2 subsurface soil sampling described above was performed in May 2021 and the data are undergoing validation.

4.2 OU4

The approach that will be taken to quantify human health and ecological risks due to exposure to impacted soils in OU4 and to determine the areas requiring remediation is described below.

4.2.1 Data Collection

Additional surface soil (0–1 ft bgs) sampling is planned for OU4 to supplement the existing PAH data set and to collect dioxin/furan data.[5] The sampling approach segregates OU4 into three subareas based on former and anticipated land use (Figure 13). The sampling protocols will be detailed in a sampling and analysis plan, which will be provided to the EPA and NCDEQ for review and approval prior to the initiation of the sampling.

4.2.1.1 Eastern Undeveloped Area

Review of aerial photos and available maps of former facility operations indicates that there were no significant activities related to the former wood treatment operations in the northeast corner of OU4. This area is referred to as the "eastern undeveloped area" for the purposes of this white paper. Sampling conducted in 2019 along the eastern property line confirmed that concentrations of PAHs in soils are below risk-based thresholds along the current OU4 eastern boundary (Figure 13) (EarthCon 2019c). Additional sampling will be conducted in the eastern undeveloped area along the boundary where past operations are known to have taken place (i.e., the former Untreated Wood Storage Area and north of the decommissioning pond footprint, Figure 13) to determine if operations-related impacts extend into the eastern undeveloped area.

The sampling strategy will follow the approach taken during the 2019 sampling to delineate the Eastern Uplands boundary (EarthCon 2019c). Five-point composite samples will be collected across a sampling area of approximately 50 by 250 ft. The samples collected in this area will be evaluated for PAHs, dioxins/furans, and pentachlorophenol (PCP), consistent with previous sampling performed in OU1 and OU2. Because this area borders the Untreated Wood Storage Area and the Pond Area, the sample analyte list will be expanded to include all the surface soils constituents of concern (COCs) identified in the HHRA for both of these areas. The additional analytes include arsenic, volatile organic compounds (VOCs; benzene, ethylbenzene, total xylenes), semivolatile organic compounds (SVOCs; 1,1-biphenyl, carbazole and dibenzofuran), and pesticides (aldrin). The sample results will be screened against residential RSLs at a cancer risk of 1×10^{-6} and HI=0.1 to determine if additional evaluation of risk is warranted.

[5] The supplemental remedial investigation will include two elements: an initial surface soil investigation and a subsequent subsurface soil and groundwater investigation. The need for additional subsurface soil sampling will be evaluated as part of the data quality objective development for the subsurface soils and groundwater investigation and will consider 1) the HHRA findings, 2) the spatial coverage of data from the existing data set and 3) the results of the additional surface soil sampling.

4.2.1.2 Pond and Process Areas above the Floodplain

The portions of the Pond and Process Areas where prior wood treatment operations took place will be subdivided into nine exposure areas (five in the Pond Area and four in the Process Area) no greater than 2 acres (Figure 13) consistent with the exposure area size designated for evaluating commercial/industrial and recreational (youth sports player) land uses, as described in Section 4.1.2. The exposure areas were delineated based on consideration of historical Site operations and the extent of contamination using existing data. Each of the exposure areas will be sampled using incremental sampling methodology (ISM), with each exposure unit representing an ISM decision unit. This sampling approach involves collection of composite samples consisting of a minimum of 30 randomly located sample increments to provide an understanding of the average contaminant concentration across the exposure area. The ISM samples collected from the Pond and Process Areas will be analyzed for PAHs, PCP, and dioxins/furans.

In addition, the Pond Area will be evaluated for the following COCs identified in the HHRA for the Pond Area: arsenic, SVOCs (1,1-biphenyl, carbazole, dibenzofuran), VOCs (ethylbenzene, benzene, total xylenes), and pesticides (aldrin). Arsenic, SVOCs, and pesticides will be analyzed in the ISM samples from the Pond Area. Discrete samples will be collected from each of the exposure areas in the Pond Area for analysis of VOCs.

4.2.1.3 Within the Floodplain

The area of OU4 that is within the floodplain is unlikely to be subject to development for human use other than to support nature trails or other natural recreational use as illustrated conceptually in Figure 2. This area will be considered as a single exposure area for the HHRA, and two exposure areas for the ERA—one in the uplands and one in the wetlands area between the uplands and the Marsh.[6] Nineteen discrete locations, 11 within the uplands area and 8 within the wetlands area (Figure 13), have been identified for surface sample collection to support calculation of parcel-specific EPCs for PAHs and dioxins/furans for evaluation of human health and ecological risks. Soil samples will be analyzed for PAHs, PCP, and dioxins/furans, consistent with previous sampling performed in OU1 and OU2. In addition, the sample analyte list for this area will be expanded to include all the surface soil COCs identified in the HHRA for the Pond Area. The additional analytes include arsenic, SVOCs (1,1-biphenyl, carbazole, dibenzofuran), VOCs (ethylbenzene, benzene, total xylenes), and pesticides (aldrin).

4.2.2 Human Health Risk Assessment

The updated data set will be used to prepare an HHRA Addendum to update the risk assessment and to include the additional receptors identified above (i.e., youth sports

[6] The decommissioning pond includes areas that are both above and below the floodplain. For the purpose of the ecological risk evaluation, the full decommissioning pond is considered to be above the floodplain.

players and site visitors/trail walkers). Table 1b presents the receptors, exposure areas, and EPC statistics that will be evaluated in the HHRA. Table 2 presents the exposure parameters that will be used. Site-specific VFs and PEFs will be derived, consistent with the agreed upon approach taken for OU2. Toxicity values for each COPC will be selected following the EPA recommended hierarchy (USEPA 2003). To evaluate cumulative noncancer effects, HQs will be summed for all COPCs and across all relevant exposure pathways to determine a noncancer HI. If the total HI for a particular receptor exceeds 1.0 for all COPCs combined and across all exposure pathways, following EPA guidance (USEPA 1989), consideration will be given as to whether the COPCs affect the same target organ or endpoint. The HHRA Addendum will support a determination of whether there are unacceptable human health risks associated with surface and subsurface soils, and an associated need for remediation. The HHRA will identify COCs and calculate SSRGs for OU4 in a manner analogous to that described for OU2 in Section 4.1.2.

4.2.3 Ecological Risk Assessment

A technical memorandum will be prepared to evaluate potential ecological risks associated with OU4. As summarized in Table 1d, potentially unacceptable ecological risks will be evaluated separately for the areas of OU4 that are outside of and within the floodplain for the land use scenarios described in Section 3. The OU4 ERA will consider the same receptors as OU2, and the approach to characterizing risks will parallel the approach described in Section 4.1.3 for OU2. Because the structure of the OU4 data set that will be derived from the sampling outlined in Section 4.2.1 will differ from the OU2 data set (which is based on parcels ≤0.25 acre in size), the specific approach to quantifying EPCs for each exposure scenario in OU4 will differ from the approach described in Section 4.1.3 for OU2. The approach for calculating EPCs for OU4 will be established later in collaboration with EPA and NCDEQ based on a review of the OU4 surface soil data. The uptake factors and TRVs for PAHs and dioxins/furans will be the same for OU4 as they were for OU1 and OU2.

As noted in Section 4.2.1, the OU4 data collection includes analysis of several constituents (arsenic, 1,1-biphenyl, carbazole, dibenzofuran, ethylbenzene, benzene, total xylenes, and aldrin) in addition to PAHs and dioxins/furans that were identified as COCs in the HHRA. The data for these constituents will be screened to determine if they need to be considered in the OU4 ERA. If needed, the uptake factors and TRVs for these constituents will be established later in collaboration with EPA and NCDEQ based on a review of the OU4 surface soil data and literature for uptake factors.

5 References

EarthCon. 2019a. Human Health Risk Assessment, Kerr-McGee Chemical Corp, Navassa, North Carolina. EarthCon Consultants of North Carolina, P.C. April.

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Figures

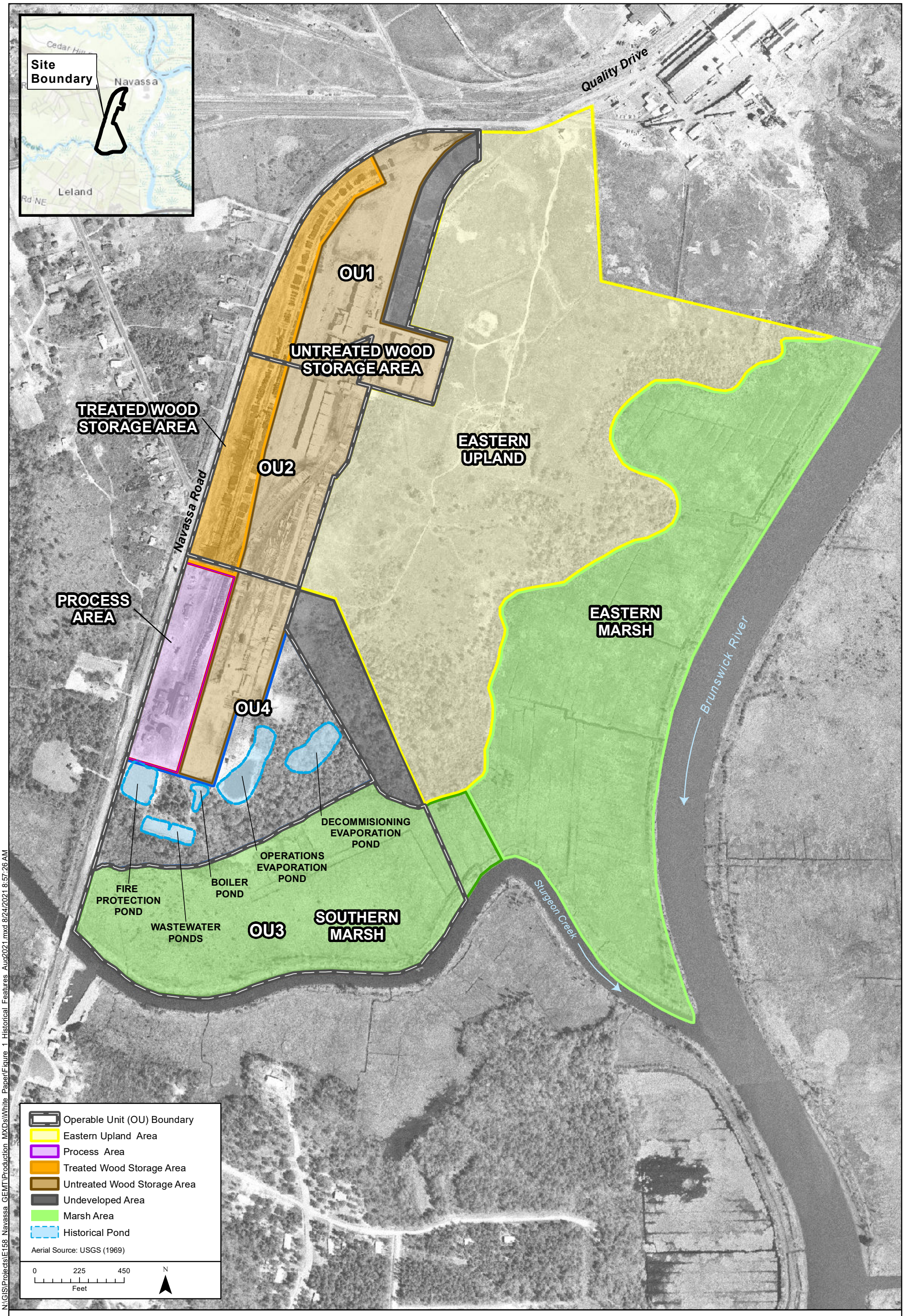

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Figure 1.
Operable Unit Layout
Kerr-McGee Chemical Corp. - Navassa Superfund Site
Navassa, North Carolina
September 2021

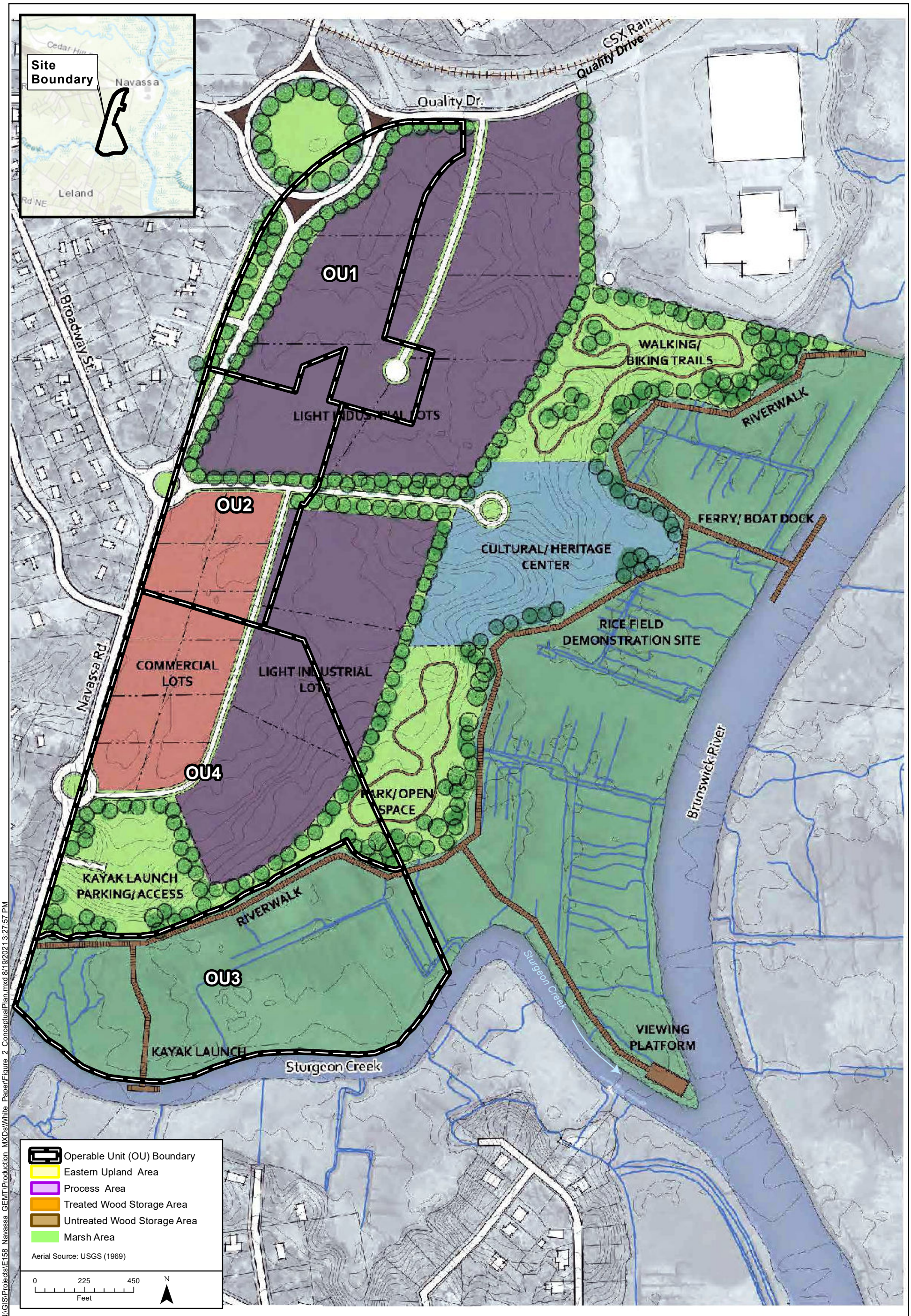

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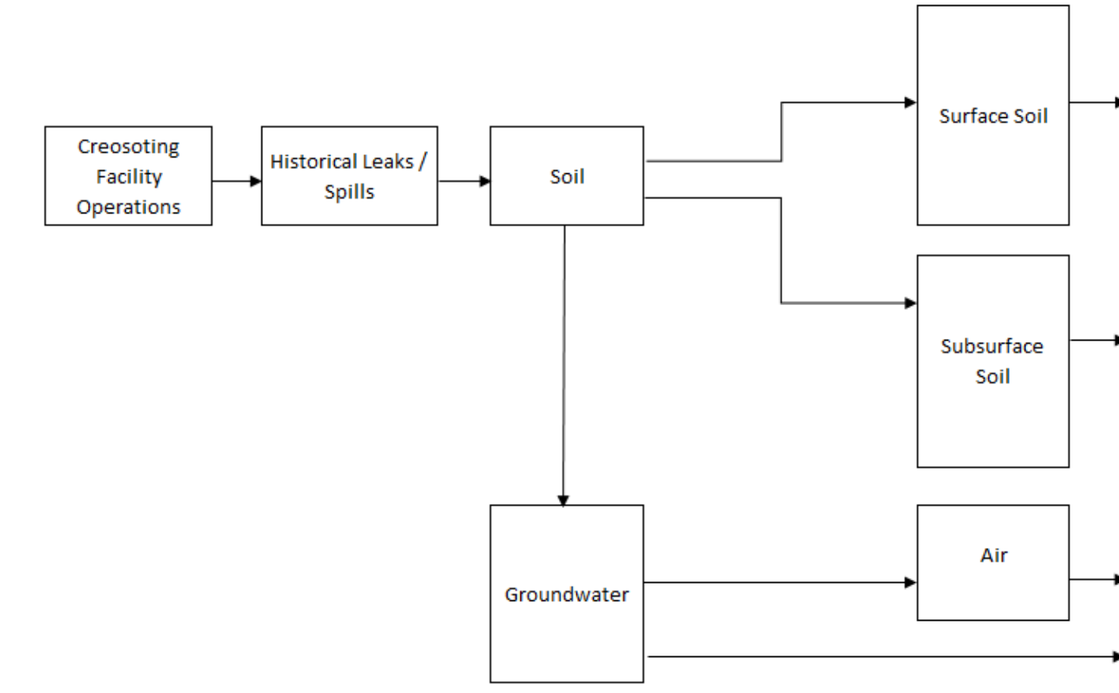
Figure 2.
Conceptual Future Land Use
Kerr-McGee Chemical Corp. - Navassa Superfund Site
Navassa, North Carolina
September 2021

TREATED AND UNTREATED WOOD STORAGE AREAS



Potential Primary Sources	Primary Release Mechanisms	Secondary Source	Transport and Migration Mechanisms	Exposure Media	Potentially Exposed Human Health Receptors: Exposure Route	Future Resident	Future Commercial/ Industrial Worker	Future Construction Worker	Current / Future Trespasser	Future Youth Sports Player	Future Site Visitor / Trail Walker
Creosoting Facility Operations	Historical Leaks / Spills	Soil		Surface Soil	Incidental Ingestion	●	●	●	●	●	●
					Dermal Contact	●	●	●	●	●	●
					Inhalation (via Particulates and Volatiles)	●	●	●	●	●	●
				Subsurface Soil	Incidental Ingestion	NA	NA	●	NA	NA	NA
					Dermal Contact	NA	NA	●	NA	NA	NA
					Inhalation (via Particulates and Volatiles)	NA	NA	●	NA	NA	NA
		Groundwater		Air	Inhalation (via Vapor Intrusion)	O	O	NA	NA	NA	NA
					Ingestion (as tap water)	O	O	NA	NA	O	O

Notes:

- ● Complete exposure route and quantitatively evaluated in the HHRA.
- O Exposure route potentially complete but qualitatively evaluated. See the report text for further details.
- NA Not Applicable - receptor is not potentially exposed via this pathway

8/18/2021

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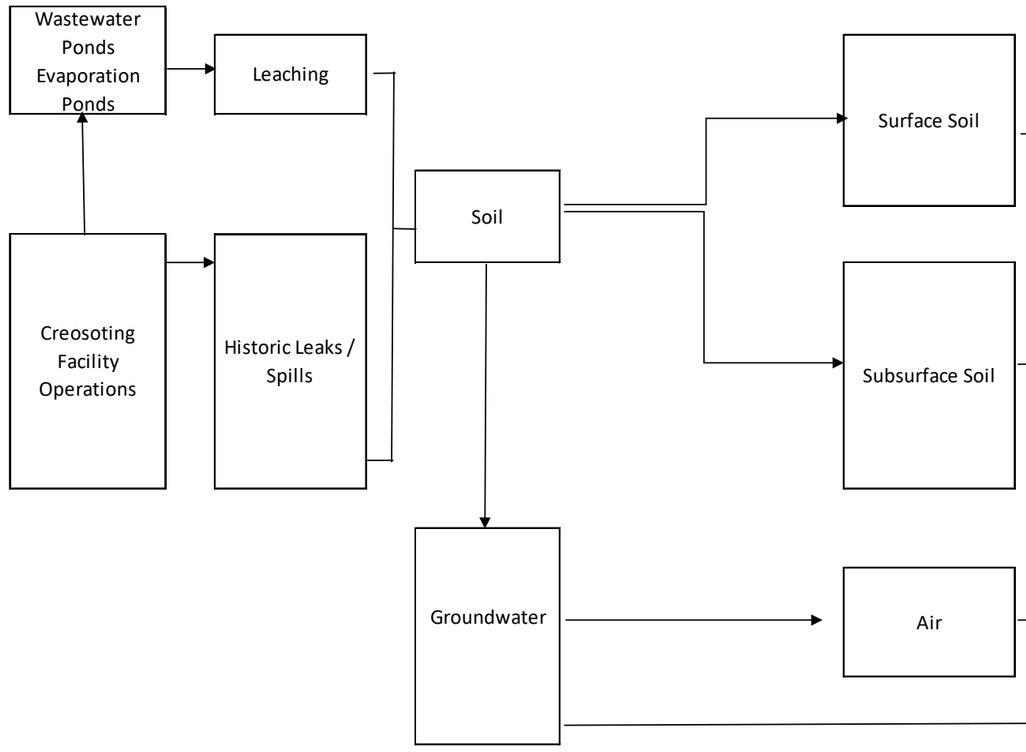
Figure 3.
OU2—Treated and Untreated Wood Storage Area: Human Health Conceptual Site Exposure Model
Kerr-McGee Chemical Corp. – Navassa Superfund Site
Navassa, North Carolina
September 2021

POND AND PROCESS AREAS



Potential Primary Sources	Primary Release Mechanisms	Secondary Source	Transport and Migration Mechanisms	Exposure Media	Potentially Exposed Receptors: Exposure Route	Future Resident	Future Commercial/ Industrial Worker	Future Construction Worker	Current / Future Trespasser	Future Youth Sports Player	Future Site Visitor / Trail Walker
Wastewater Ponds Evaporation Ponds; Creosoting Facility Operations	Leaching; Historic Leaks / Spills	Soil		Surface Soil	Ingestion	●	●	●	●	●	●
					Dermal Contact	●	●	●	●	●	●
					Inhalation (via Particulates and Volatiles)	●	●	●	●	●	●
				Subsurface Soil	Incidential Ingestion	NA	NA	●	NA	NA	NA
					Dermal Contact	NA	NA	●	NA	NA	NA
					Inhalation (via Particulates and Volatiles)	NA	NA	●	NA	NA	NA
		Groundwater		Air	Inhalation (via Vapor Intrusion)	●	●	NA	NA	NA	NA
					Ingestion (as tap water)	●	●	NA	NA	●	●

Notes:

● Complete exposure route and quantitatively evaluated in the HHRA.

NA Not Applicable - receptor is not potentially exposed via this pathway

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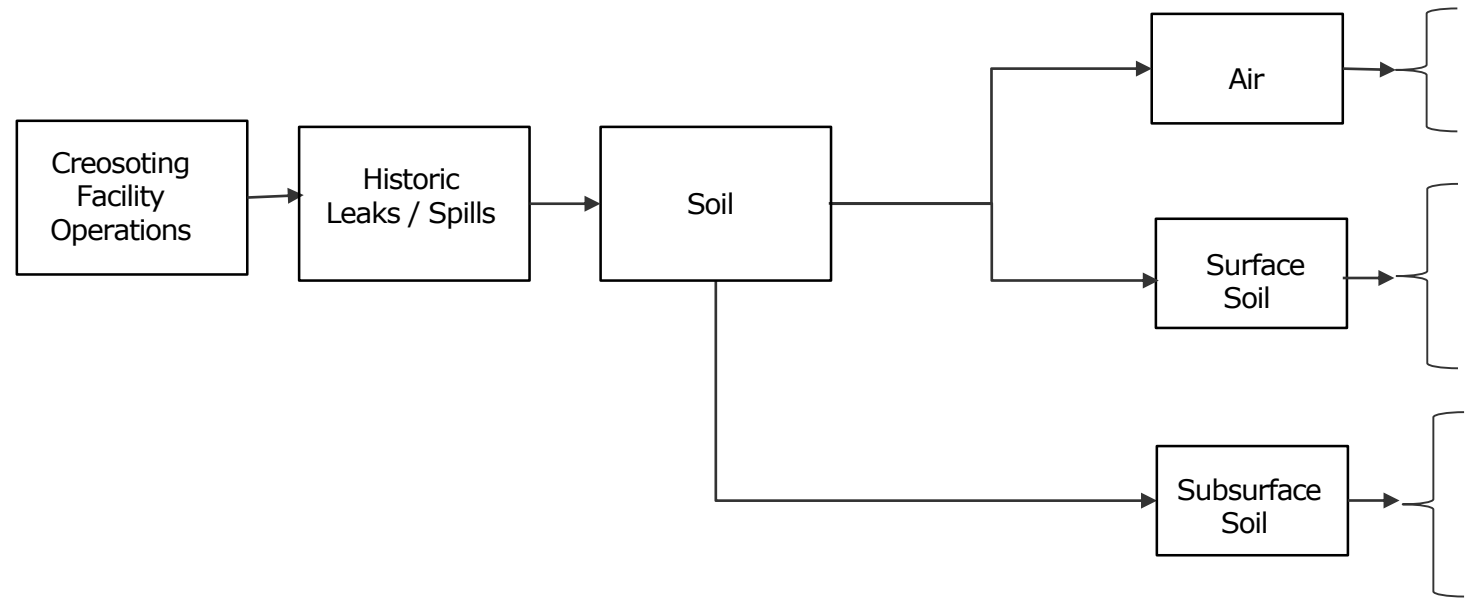
Prepared by: integral engineering pc; EARTHCON; RAMBOLL

Figure 4.
OU4—Treated and Untreated Wood Storage Area: Human Health Conceptual Site Exposure Model
Kerr-McGee Chemical Corp. – Navassa Superfund Site
Navassa, North Carolina
September 2021



Exposure Route	Terrestrial Receptors: Off-site Birds
Inhalation of soil particles	I
Direct Contact	Y
Ingestion	Y
Direct Contact	N
Ingestion	N

Key:

Y The pathway is complete and is quantitatively evaluated in this environmental risk characterization

I The pathway is potentially complete but insignificant relative to other pathways, and is not evaluated further

N The pathway is not complete and is not evaluated

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RAMBOLL

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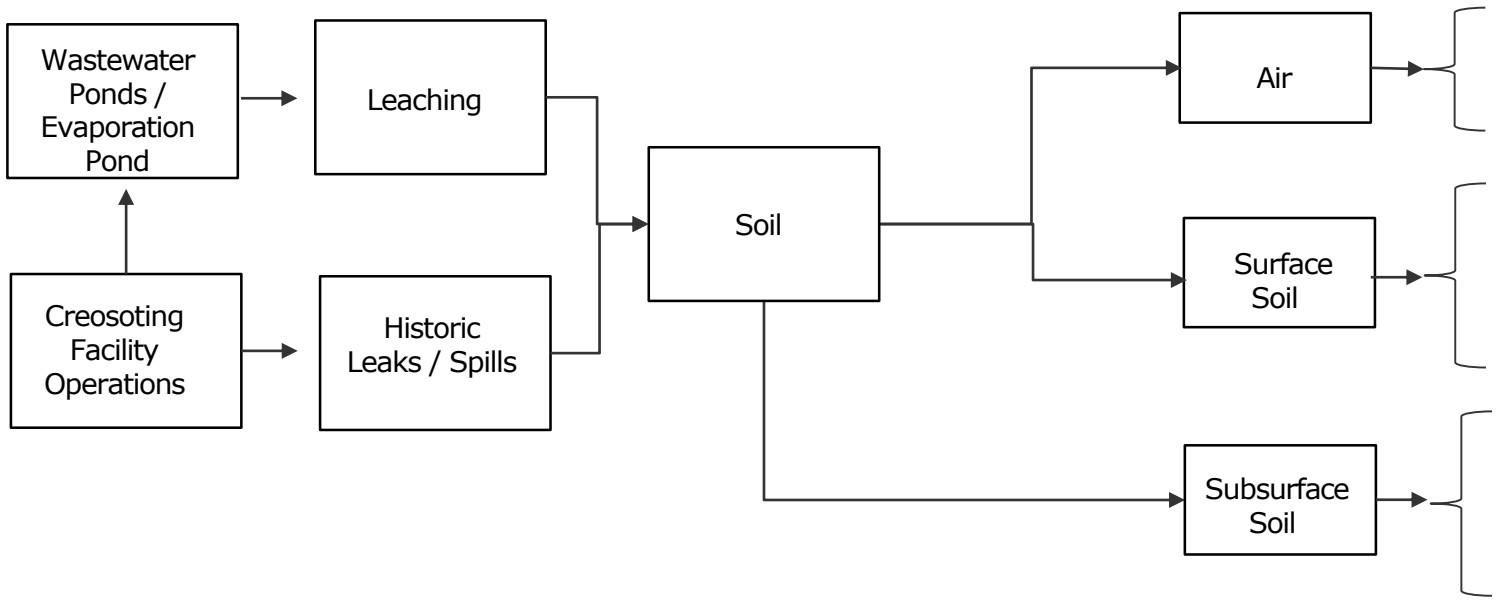
OU2 – Residential, Commercial/Industrial, and/or Sports Field Land Use: Ecological Conceptual Site Exposure Model

Figure 5



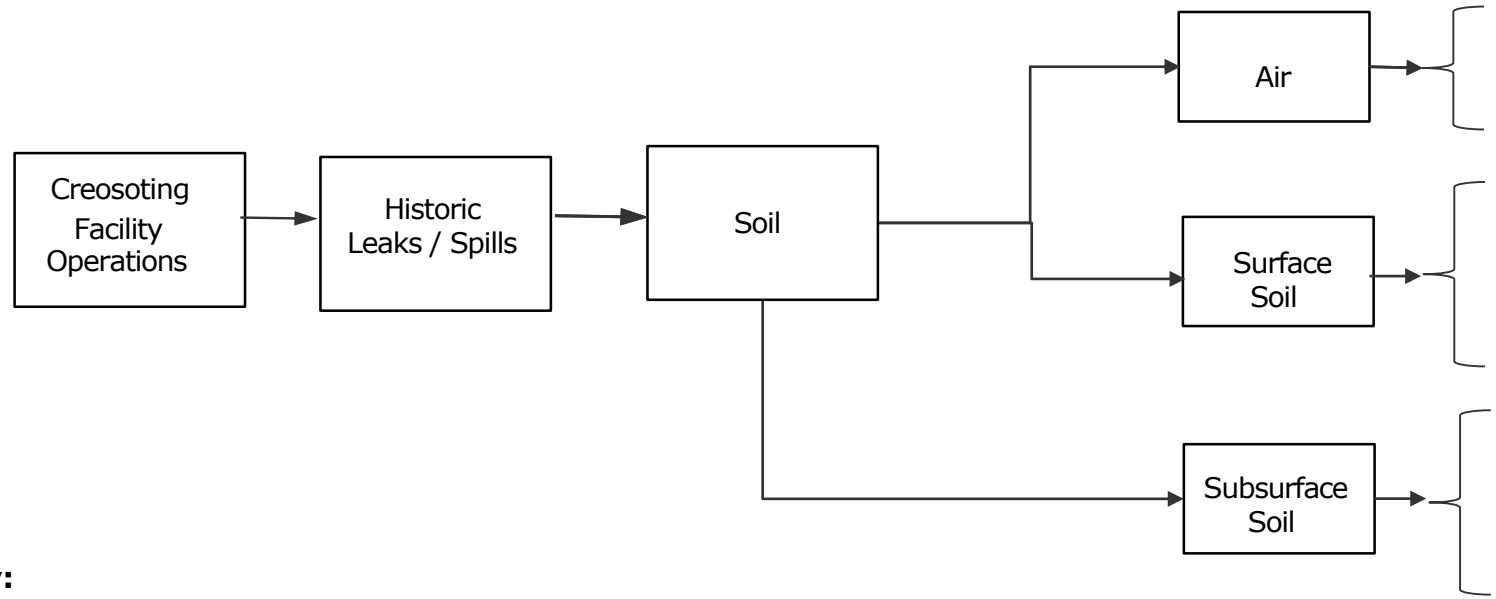
Exposure Route	Terrestrial Receptors: Off-site Birds
Inhalation of soil particles	I
Direct Contact	Y
Ingestion	Y
Direct Contact	N
Ingestion	N

Key:

Y The pathway is complete and is quantitatively evaluated in this environmental risk characterization

I The pathway is potentially complete but insignificant relative to other pathways, and is not evaluated further

N The pathway is not complete and is not evaluated



Exposure Route (a)	Terrestrial Receptors		
	Invertebrates	Birds	Mammals
Inhalation of soil particles	I	I	I
Direct Contact	Y	Y	Y
Ingestion	Y	Y	Y
Direct Contact	N	N	Y
Ingestion	N	N	Y

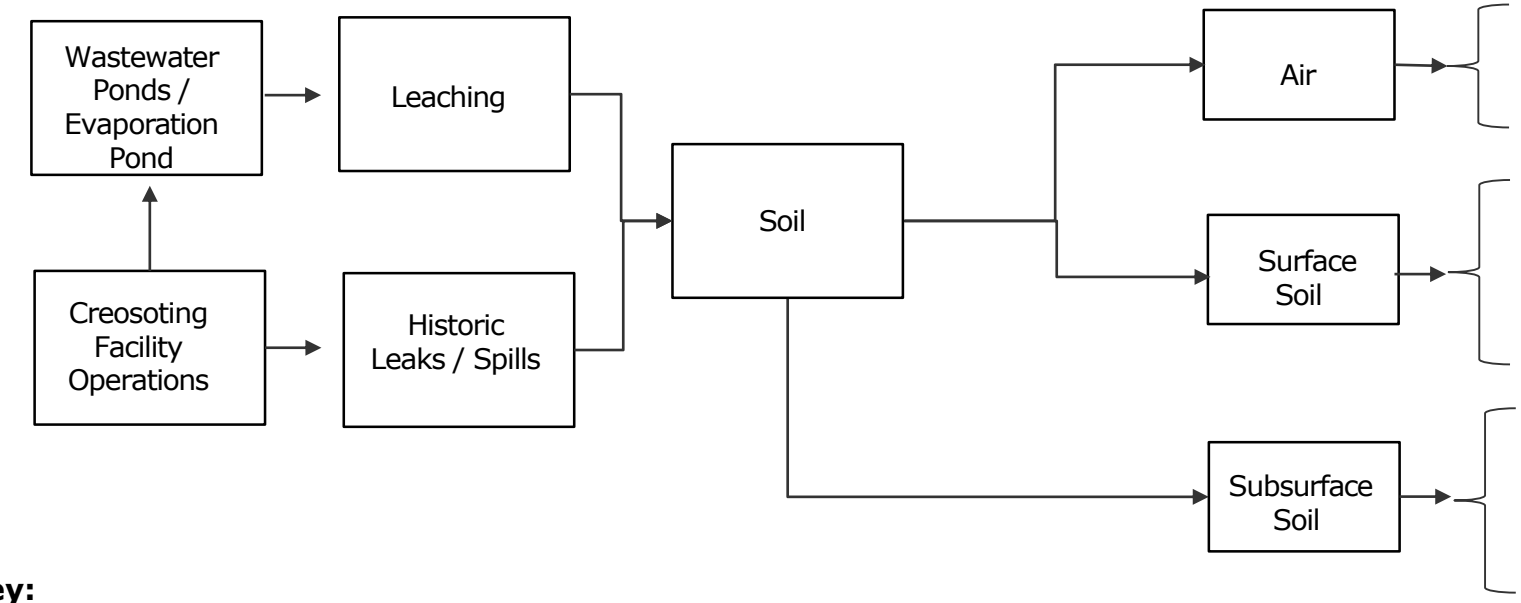
Key:

Y The pathway is complete and is quantitatively evaluated in this environmental risk characterization

I The pathway is potentially complete but insignificant relative to other pathways, and is not evaluated further

N The pathway is not complete and is not evaluated

(a) For Exposure Route, "Direct Contact" and "Ingestion" includes direct contact, direct soil ingestion, and ingestion of prey that has been in contact with the media (soil) from the OU.



Exposure Route	Terrestrial Receptors		
	Invertebrates	Birds	Mammals
Inhalation of soil particles	I	I	I
Direct Contact	Y	Y	Y
Ingestion	Y	Y	Y
Direct Contact	N	N	Y
Ingestion	N	N	Y

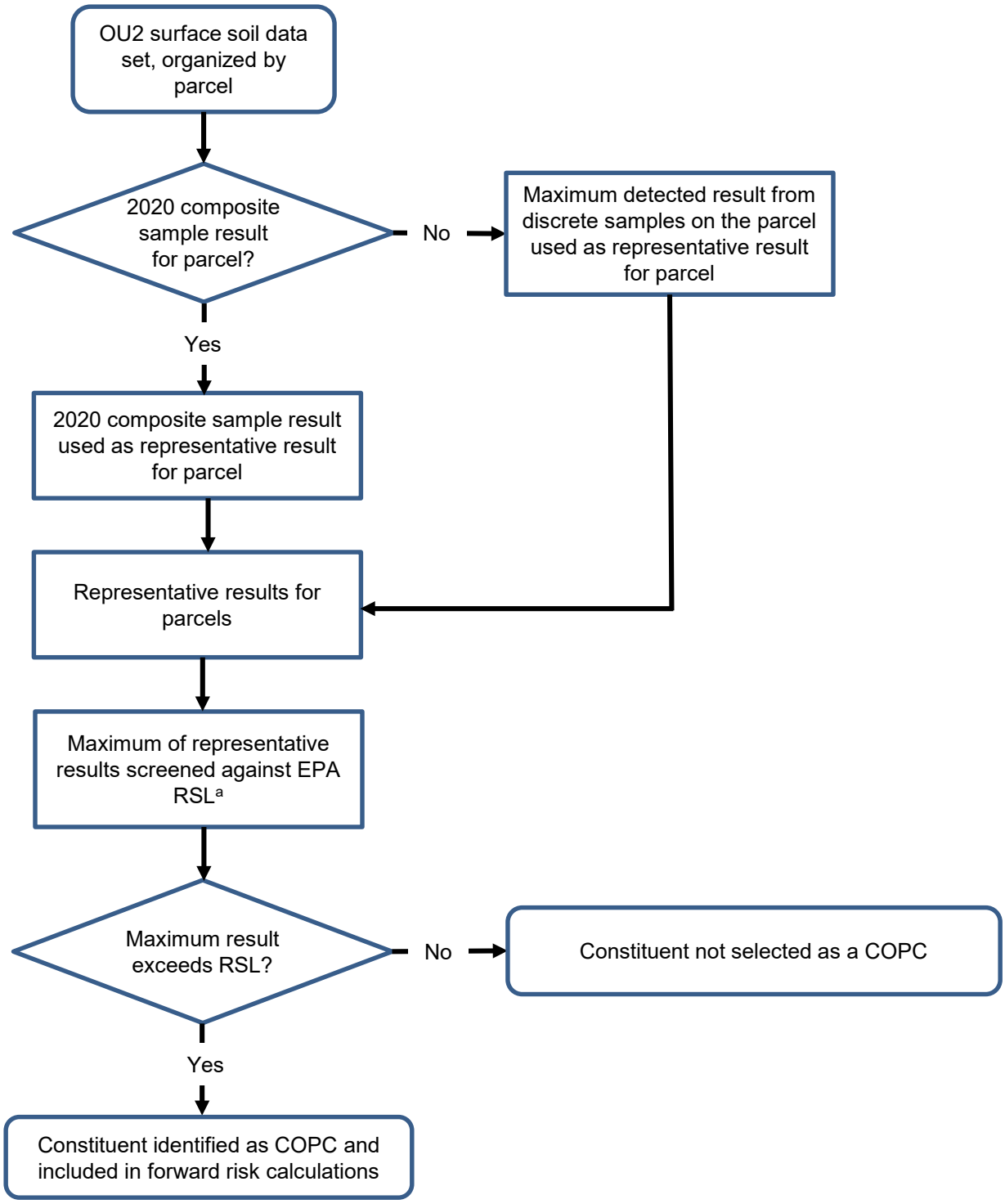
Key:

Y The pathway is complete and is quantitatively evaluated in this environmental risk characterization

I The pathway is potentially complete but insignificant relative to other pathways, and is not evaluated further

N The pathway is not complete and is not evaluated

(a) For Exposure Route, "Direct Contact" and "Ingestion" includes direct contact, direct soil ingestion, and ingestion of prey that has been in contact with the media (soil) from the OU.



Notes:
COPC = constituent of potential concern
HHRA = human health risk assessment
OU = operable unit

[a] Regional screening levels (RSLs) were obtained from the USEPA Residential Soil Table (TR = 1E-06, THQ = 0.1), May 2021.

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Figure 9.
Surface Soil Data Evaluation and COPC Identification for the OU2 HHRA
Kerr-McGee Chemical Corp. - Navassa Superfund Site
Navassa, North Carolina
September 2021

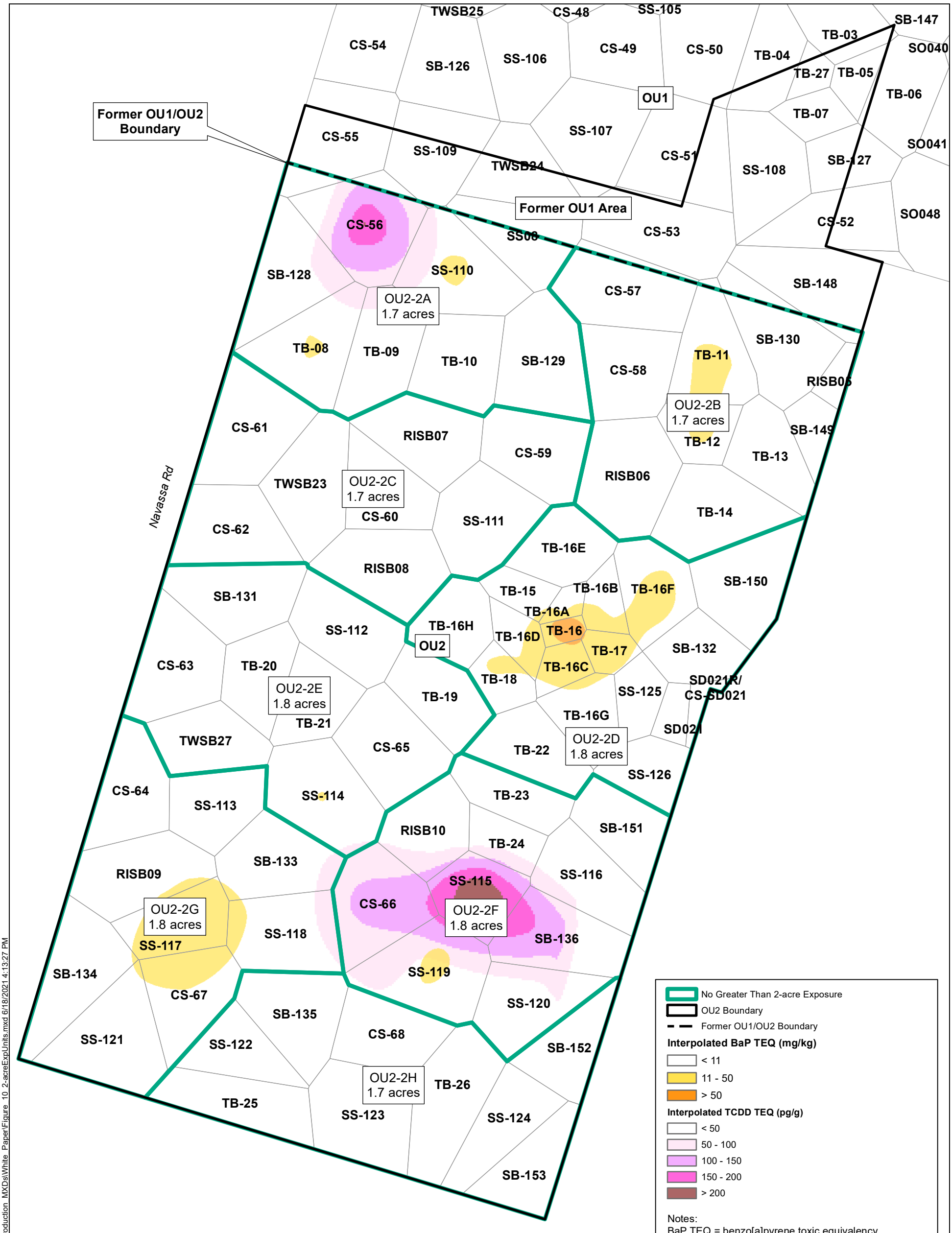

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Figure 10.
OU2 Human Health Exposure Areas No Greater Than 2 acres
Kerr-McGee Chemical Corp. - Navassa Superfund Site
Navassa, North Carolina
September 2021

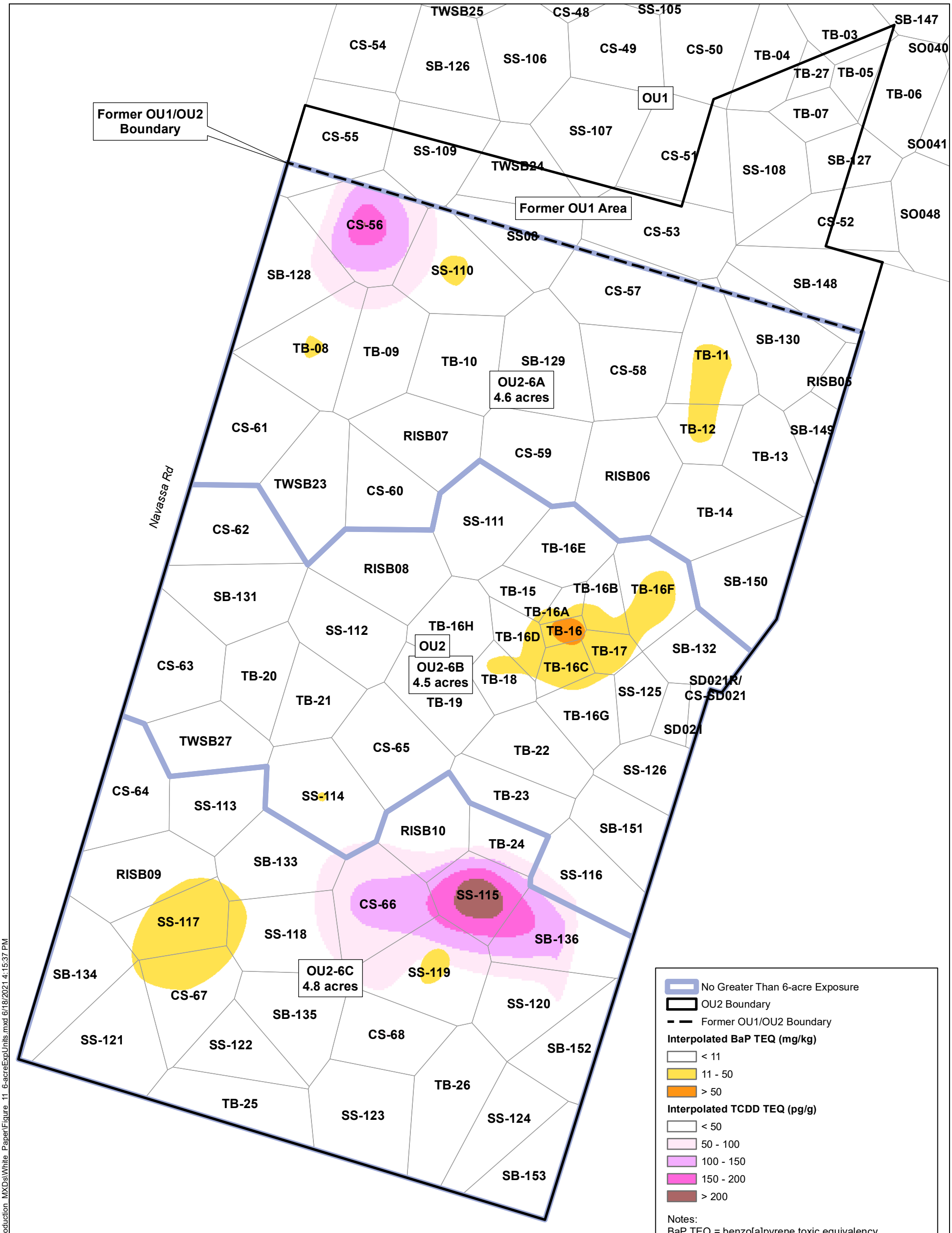

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Figure 11.
OU2 Human Health Exposure Areas No Greater Than 6 acres
Kerr-McGee Chemical Corp. - Navassa Superfund Site
Navassa, North Carolina
September 2021

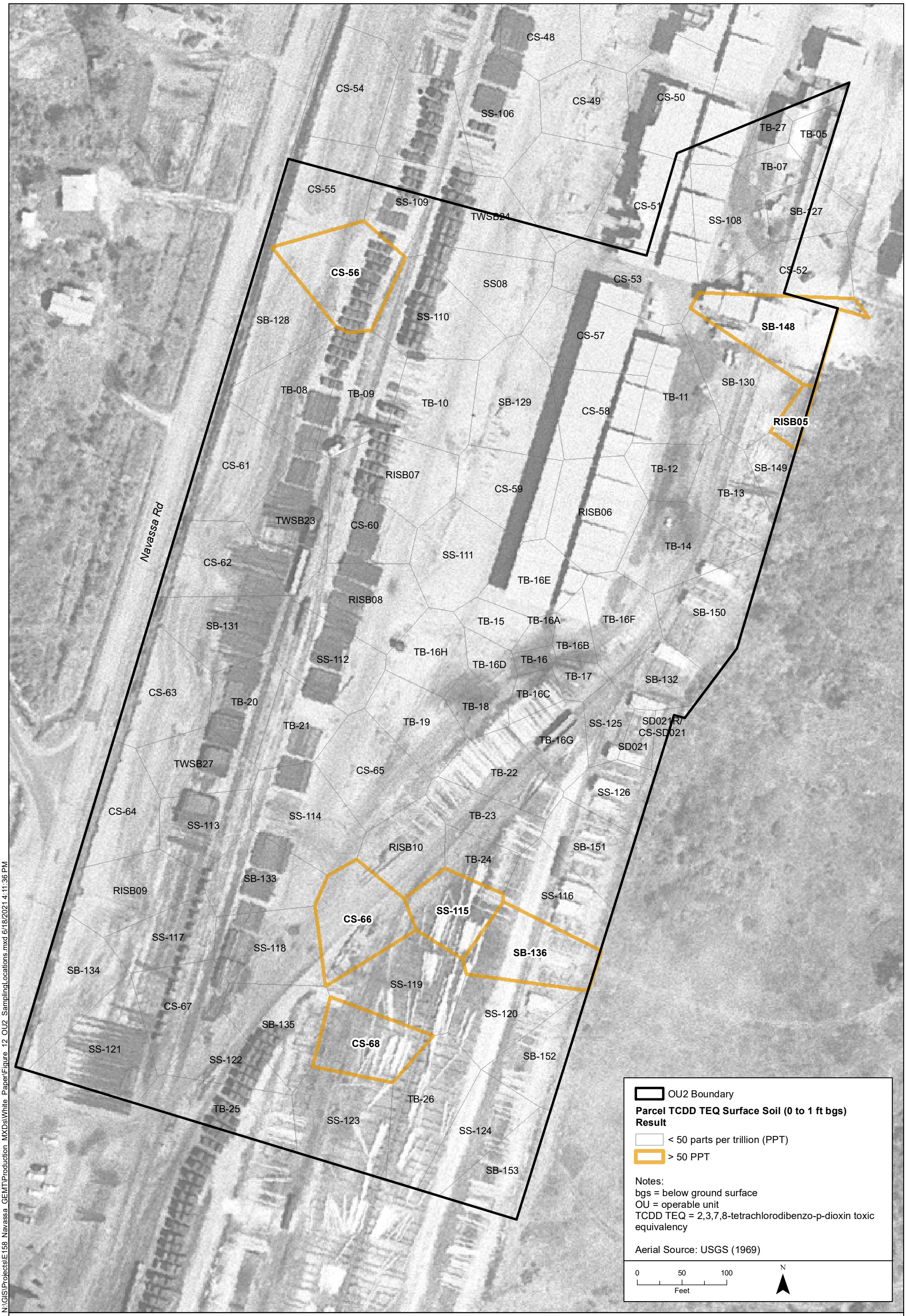

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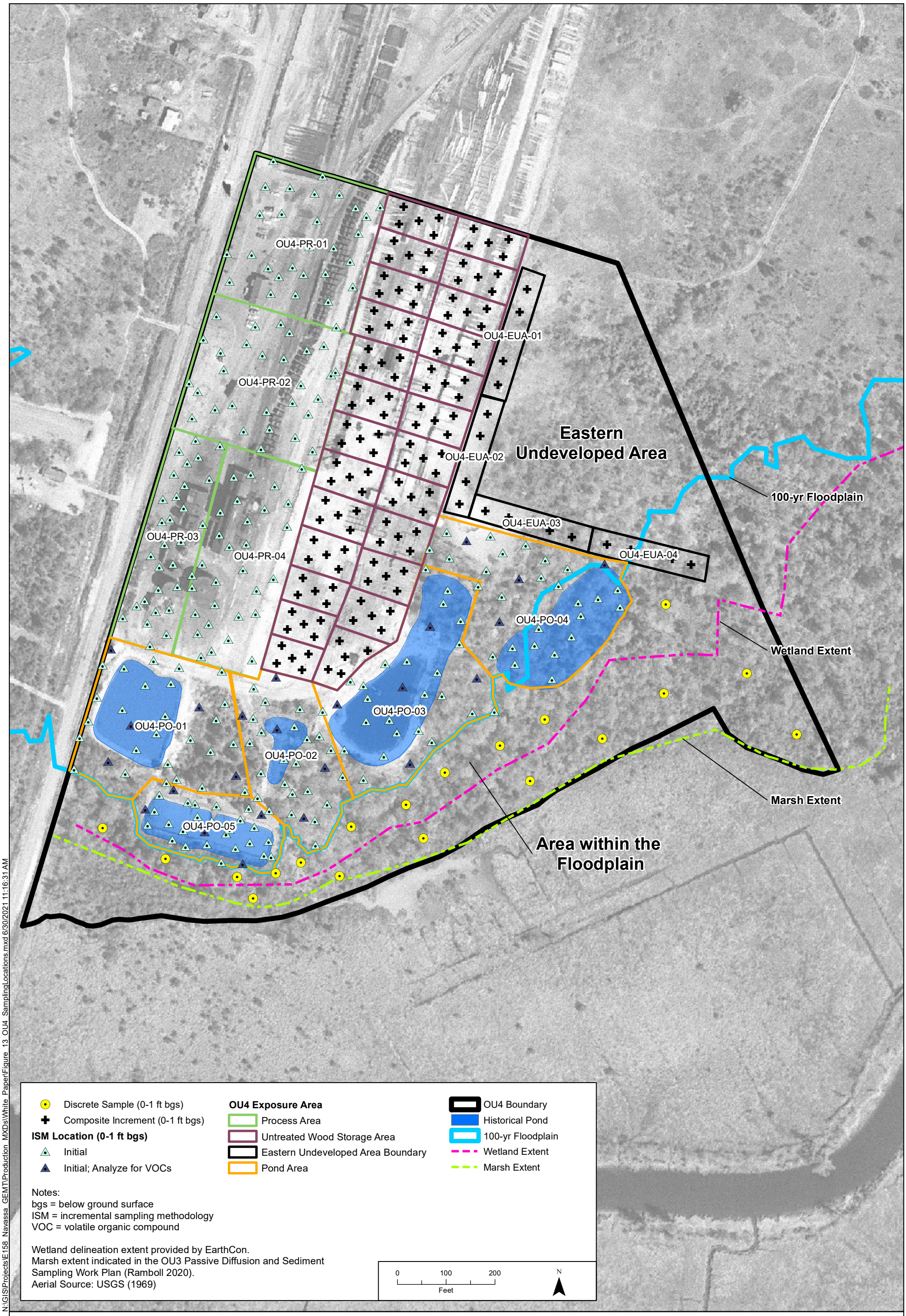
Figure 12.
OU2 Parcels with Surface Soil TCDD TEQ Greater Than 50 PPT
Kerr-McGee Chemical Corp. - Navassa Superfund Site
Navassa, North Carolina
September 2021



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Prepared by: integral engineering pc

Figure 13.
Proposed OU4 Human Health Exposure Areas and Sample Locations
Kerr-McGee Chemical Corp. - Navassa Superfund Site
Navassa, North Carolina
September 2021

Tables

Table 1A
Human Receptors Based on OU2 Land Use
Kerr-McGee Chemical Corporation Superfund Site
Navassa, North Carolina

Land Use Scenarios	Potential Human Receptors	Human Health Exposure Area	Basis of Human Health EPC
Future Residential	Resident, Construction Worker[a]	No Greater Than 0.25 Acre	Composite Sample Result or Maximum of Discrete Samples Result if No Composite Sample Result Available
Future Industrial Commercial	Commercial/Industrial Worker, Construction Worker	No Greater Than 2 Acres (1.7 - 1.8)	SWAC
Future Recreational - Sports Field	Youth Sports Player, Construction Worker	No Greater Than 2 Acres (1.7 - 1.8)	SWAC
Current Conditions	Trespasser	No Greater Than 2 Acres (1.7 - 1.8)	SWAC
Future Recreational - Nature Trails	Site Visitor/Trail Walker	No Greater Than 6 Acres (4.5 - 4.8)	SWAC

Notes:
EPC - exposure point concentration
SWAC - surface weighted average concentration

[a] The quantitative evaluation for construction workers will be completed assuming exposure to soils in exposure areas no greater than 2 acres using an ISM or maximum discrete sample as the EPC.

Table 1B
Human and Ecological Receptors Based on OU4 Land Use
Kerr-McGee Chemical Corporation Superfund Site
Navassa, North Carolina

Area	Land Use Scenarios	Potential Human Receptors	Human Health Exposure Area	Basis of Human Health EPC
OU4 above the Floodplain	Future Residential	Resident, Construction Worker[a]	Untreated Wood Storage Area - No Greater Than 0.25 Acre Pond and Process Areas - No Greater Than 2 Acres	Composite result; ISM: ISM result or 95UCL if triplicate is available; Discrete: maximum of discrete sample results.
	Future Industrial Commercial	Outdoor Worker, Construction Worker	No Greater Than 2 Acres	ISM: ISM result or 95UCL if triplicate is available; Discrete: maximum of discrete sample results.
	Future Recreational - Sports Field	Youth Sports Player, Construction Worker	No Greater Than 2 Acres	ISM: ISM result or 95UCL if triplicate is available; Discrete: maximum of discrete sample results.
	Current Conditions	Trespasser	No Greater Than 2 Acres	ISM: ISM result or 95UCL if triplicate is available; Discrete: maximum of discrete sample results.
	Future Recreational - Nature Trails	Site Visitor/Trail Walker	No Greater Than 6 Acres	ISM: ISM result or 95UCL if triplicate is available; Discrete: maximum of discrete sample results.
OU4 below the Floodplain	Current Conditions	Trespasser	No Greater Than 2 Acres	Discrete: Lesser of maximum result and 95UCL of discrete sample results
	Future Recreational - Nature Trails	Site Visitor/Trail Walker	No Greater Than 6 Acres	Discrete: Lesser of maximum result and 95UCL of discrete sample results

Notes:
EPC - exposure point concentration
ISM - incremental sampling methodology
UCL - upper confidence limit

[a] The quantitative evaluation for construction workers will be completed assuming exposure to soils in exposure areas no greater than 2 acres using an ISM or maximum discrete sample as the EPC.

Table 1C
Ecological Receptors Based on OU2 Land Use
Kerr-McGee Chemical Corporation Superfund Site
Navassa, North Carolina

Area	Land Use Scenarios	Potential Ecological Receptors	Ecological Exposure Area	Basis of Ecological EPC
OU2	Future Residential, Industrial/Commercial, Recreational - Sports Field	Small Home Range Songbird and Mammal Species	2-Acre Exposure Areas Drawn around Highest Concentrations	SWAC
		Large Home Range Songbird Species	All of OU2 - 15.6 acres	SWAC
OU2	Current Conditions Future Recreational - Nature Trails	Small Home Range Songbird and Mammal Species	2-Acre Exposure Areas Drawn around Highest Concentrations	SWAC
		Large Home Range Songbird and Mammal Species	All of OU2 - 15.6 acres	SWAC
		Invertebrates	Each Individual Polygon Is Considered	Composite Sample Result or UCL or Maximum of Discrete Samples Result if No Composite Sample Result Available

Notes:
EPC - exposure point concentration
SWAC - surface weighted average concentration
UCL - upper confidence limit

Table 1D
Ecological Receptors Based on OU4 Land Use
Kerr-McGee Chemical Corporation Superfund Site
Navassa, North Carolina

Area	Land Use Scenarios	Potential Ecological Receptors	Ecological Exposure Area
OU4 above the Floodplain	Future Residential, Industrial/Commercial, Recreational - Sports Field	Small Home Range Songbird Species	2-Acre
		Large Home Range Songbird Species	All of OU4
	Current Conditions Future Recreational - Nature Trails	Small Home Range Songbird and Mammal Species	2-Acre
		Large Home Range Songbird and Mammal Species	All of OU4
		Invertebrates	NA. Invertebrates will be evaluated for each individual soil sample
OU4 within the Floodplain	Current Conditions Future Residential, Industrial/Commercial, Recreational - Sports Field Recreational - Nature Trails	Small Home Range Songbird and Mammal Species	2-Acre
		Large Home Range Songbird and Mammal Species	All of OU4
		Invertebrates	NA. Invertebrates will be evaluated for each individual soil sample

Notes:
EPC - exposure point concentration
SWAC - surface weighted average concentration
UCL - upper confidence limit
NA - not applicable

Table 2
Summary of Receptor-Specific Exposure Parameters
Kerr-McGee Chemical Corporation Superfund Site
Navassa, North Carolina

Exposure Parameter	Units	Potential Human Receptors					
		Lifetime Resident (0-26 years) [a]	Commercial/ Industrial Worker [a]	Trespasser [a]	Construction Worker [a,b]	Youth Sports Player	Site Visitor/ Trail Walker
Body Weight (BW)	kg	15 (child); 80 (adult)	80	45	80	45	15 (child); 80 (adult)
Exposure Duration (ED)	years	6 (child); 20 (adult)	25	10	1	10	6 (child); 20 (adult)
Exposure Frequency (EF)	days/year	350	250	45	250	150	78
Exposure Time (ET)	hours	24	8	2	8	2	2
Soil Ingestion Rate (IRS)	mg/day	200 (child); 100 (adult)	100	150	330	90	90 (child); 50 (adult);
Adherence Factor (AF)	mg/cm^2	0.2 (child); 0.07 (adult)	0.12	0.135	0.3	0.2	0.2 (child); 0.07 (adult)
Skin Absorption Factor (ABS)	unitless	Chemical-specific from USEPA RSLs					
Exposed Surface Area (SA)	cm^2	2,373 (child); 6,032 (adult)	3,527	4,203	3,527	3,935	2,373 (child); 6,032 (adult)
Particulate Emission Factor (PEF)	m^3/kg	See Attachment 1.					
Volatilization Factor (VF)	m^3/kg	Chemical-specific, See Attachment 1.					

Notes:
(a) Exposure parameters were defined in, and approved for the 2019 HHRA.
(b) Construction workers are the only potential receptors for subsurface soils.

Table 3
Exposure Parameters for Ecological Receptors
Kerr-McGee Chemical Corporation Superfund Site
Navassa, North Carolina

Guild	Name	Species	Water IR w (L/day)	Food IR f (kg ww/day)	(kg dw/day)	Notes	Surface Soil IR ss % (a)	(kg dw/day)	Diet (b) Plants	Above-ground Inverte-brates	Below-ground Inverte-brates	BW (kg)	Range (c) (ha)	AUF (unitless) Conser-vative	OU2 Species-Specific (≤1) Using 6.3 hectares
Insectivore	American Robin	*Turdus migratorius*	0.0113	0.123	0.0252	Earthworms (d)	5	0.001262	0-0.5	0-0.35	0.35-1	0.0810	0.160	1	1
					0.0197	Plants (d)		0.000985							
					0.0236	Aboveground		0.00118							
Insectivore	American Woodcock	*Scolopax minor*	0.0175	0.203	0.0416	Earthworms (d)	10.4	0.00433	0	0-0.5	0.5-1	0.175	10.0	1	0.63
					0.0390	Aboveground Invertebrates (d)		0.00405							
Omnivore	Raccoon	*Procyon lotor*	0.496	1.49	0.305	Earthworms (d)	9.4	0.0287	0.2	0-0.40	0.4-0.8	5.98	52.0	1	0.12
					0.238	Plants (d)		0.0224							
					0.286	Aboveground Invertebrates (d)		0.0269							
Insectivore	Short-tailed Shrew	*Blarina brevicauda*	0.00493	0.0138	0.00282	Earthworms (d)	3.7	0.000104	0	0-0.5	0.5-1	0.0170	0.390	1	1
					0.00220	Plants (d)		0.0000815							
					0.00264	Aboveground Invertebrates (d)		0.0000978							

OU2 Site (acres): 15.6
OU2 Site (hectares): 6.3

Notes:

≤	Less than or equal to	IR ss	Ingestion rate of surface soil (dry weight)
AG	Aboveground invertebrates	IR w	Ingestion rate of water
AUF	Area use factor	kg	Kilograms
BW	Body weight	kg dw/day	Kilograms dry weight per day
EU	Undepurated belowground invertebrates	kg ww/day	Kilograms wet weight per day
ha	Hectares	L/day	Liters per day
IR f	Ingestion rate of food (wet weight)	NA	Not applicable

(a) The ingestion rate for this OU2 ERA is 5% for robin and 10.4% for woodcock. Previous work for OU1 and OU2 have included robin ingestion rates of 5% and 10.4% as part of an uncertainty assessment. The USEPA Exposures Factors Handbook and USEPA R4 exposure parameters both show 5% ingestion rate for the robin. The 10.4% ingestion rate for the robin is not included as an uncertainty assessment.

(b) Different diet scenarios are evaluated in the total daily intake calculations for each receptor. Also, invertebrates are evaluated as both aboveground and belowground invertebrates. Woodcocks only eat invertebrates; therefore, their diet evaluation is 100% invertebrates but evaluated by invertebrate type. For mammals, there will be two different diet scenarios evaluated: one conservative and one realistic.

Bird Diet Scenarios:		**Robin**	**Woodcock**
Scenario 1	100% Belowground Invertebrates	X	X
Scenario 2	50% Plants and 50% Belowground Invertebrates	X	NA
Scenario 3	50% Belowground and 50% Aboveground Invertebrates	X	X
Scenario 4	30% Plants, 35% Belowground and 35% Aboveground Invertebrates	X	NA

Mammal Diet Scenarios:	
Shrew (Conservative):	100% Belowground Invertebrates
Shrew (Realistic)	50% Belowground and 50% Aboveground Invertebrates
Raccoon (Conservative):	20% Plants and 80% Belowground invertebrates
Raccoon (Realistic)	20% Plants, 40% Aboveground, and 40% Belowground invertebrates

(c) USEPA R4 guidance document (USEPA R4 2016) presents home range of receptors in hectares. For American woodcock, USEPA R4 (2016) guidance suggested a home range of 10.5 hectares; however, the USEPA R4 (2020) screening discussed a home range of 25 acres which converts to 10 hectares. 10 hectares was used for the American woodcock in the food web model.

(d) Assumed a diet moisture content of 84% to convert from wet weight to dry weight for plants (USEPA, 1993; USEPA R4, 2020); however, the 95% UCL of measured moisture data was used to convert from wet weight to dry weight for belowground invertebrates and aboveground invertebrates:

Literature-sourced % Plant Moisture:	84	% Solids Plants:	16.0
% Moisture AG (95% UCL):	80.8	% Solids AG:	19.2
% Moisture EU (95% UCL):	79.5	% Solids EU:	20.5

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USEPA R4. 2016. "EPA Region 4 Preferred Parameters to be Used in Ecological Risk Assessment in Region 4 – Version 9 – Last Revised November 01, 2016." Received by email from Brett Thomas, USEPA Region 4, on June 26, 2017.

USEPA R4. 2020. Revised Semi-Screening Level Ecological Risk Assessment Calculations for OU1 of the Kerr-McGee Chemical Company Site in Navassa, North Carolina. Received by email from Erik Spalvins via EarthCon on October 19, 2020.

Attachment 1

Site-Specific PEF and VF Calculations

Attachment 1-1. Site-Specific Particulate Emission Factor Calculations

Chronic Particulate Emission Factor for a Resident, Site Visitor/Trail Walker, Youth Sports Player, Trespasser, and Commercial/Industrial Worker

$$PEF_{wind} = Q/C_{wind} \times \left[\frac{3600}{0.036 \times (1-V) \times \left(\frac{U_m}{U_t}\right)^3 \times F(x)} \right]$$

PEF_{wind}	=	4.1E+10	m³/kg	Chronic particulate emission factor
Q/C_{wind}	=	48.6	(g/m^2-sec per kg/m^3)	Chronic dispersion factor for fugitive dust emissions from soil (calculated) Q/C_{wind} = A x exp [(ln A_s - B)^2/C]
A_s	=	4.8	acres	Areal extent of site soil contamination (site-specific)
A	=	12.3675	unitless	Dispersion constant for Raleigh, NC (NCDEQ 2020)
B	=	18.6337	unitless	Dispersion constant for Raleigh, NC (NCDEQ 2020)
C	=	212.7284	unitless	Dispersion constant for Raleigh, NC (NCDEQ 2020)
F(x)	=	0.0085	unitless	Function of x; if x< 2, F(x) = 1.91207 - 0.0278085x + 0.48113x^2 - 1.09871x^3 + 0.335341x^4 (calculated) if x ≥ 2, F(x) = 0.18 × (8x³ + 12x) × exp(-x²) (calculated)
x	=	2.916	unitless	Function of U_t/U_m; x = 0.886 × (U_t/U_m) (calculated)
U_m	=	3.44	m/sec	Mean annual wind speed for Raleigh, NC (NCDEQ 2020)
U_t	=	11.32	m/sec	Equivalent threshold value of wind speed at 7 meters (USEPA 2002)
V	=	0.5	unitless	Fraction vegetative cover (USEPA 2002)

Attachment 1-1. Site-Specific Particulate Emission Factor Calculations

Subchronic Particulate Emission Factor for a Construction Worker

$$PEF_{sc} = Q/C_{sr} \times \frac{1}{F_D} \times \left[\frac{T \times A_R}{556 \times \left(\frac{W}{3}\right)^{0.4} \times \frac{365 - p}{365} \times \sum VKT} \right]$$

PEF_{sc}	=	1.4E+06	m^3/kg	Subchronic particulate emission factor
Q/C_{sr}	=	18.7	(g/m^2-sec per kg/m^3)	Subchronic dispersion factor for fugitive dust emissions from soil (calculated) $Q/C_{sr} = A \times \exp[(\ln A_s - B)^2/C]$
A_s	=	1.8	acres	Areal extent of site soil contamination requiring construction (site-specific)
A	=	12.9351	unitless	Dispersion constant (USEPA 2002)
B	=	5.7383	unitless	Dispersion constant (USEPA 2002)
C	=	71.7711	unitless	Dispersion constant (USEPA 2002)
F_D	=	0.186	unitless	Dispersion correction factor $F_D = 0.1852 + (5.3537/t_c) + (-9.6318/t_c^2)$ (calculated)
ED	=	1	year	Exposure duration (EarthCon 2019)
EW	=	50	weeks/year	Weeks worked during construction (BPJ; site-specific)
EF	=	250	days/year	Exposure frequency (EarthCon 2019)
ET	=	8	hours/day	Exposure time (EarthCon 2019)
t_c	=	8,400	hours	Duration of construction t_c = ED x EW x 7 days/wk x 24 hrs/day (calculated)
T	=	7.2E+06	seconds	Overall duration of traffic T = ED x EF x ET x 3,600 seconds/hour (calculated)
A_R	=	520	m^2	Surface area of contaminated road $A_R = L_R \times W_R$ (calculated)
L_R	=	85	meters	Length of road segment $L_R = (A_s \times 4{,}047$ meter/acre$)^{0.5}$ (calculated)
W_R	=	6.1	meters	Width of the road segment W_R = 20 ft x 0.3048 meter/ft (USEPA 2002)
W	=	11	tons	Mean vehicle weight W = [(10 cars x 2 tons/car) + (10 trucks x 20 tons/truck)] / 20 vehicles (BPJ; site-specific)
p	=	120	days/year	Number of days with 0.01 inches of precipitation (region-specific; USEPA 2002)
V	=	20	unitless	Number of vehicles (BPJ; site-specific)
Z	=	1	unitless	Number of times the vehicles travel down the road (BPJ; site-specific)
ΣVKT	=	427	km	Sum of fleet vehicle kilometers traveled during construction $\sum VKT = V \times L_R \times EF \times Z$ (calculated)

References:

EarthCon. 2019. Human Health Risk Assessment, Kerr-McGee Chemical Corp - Navassa Superfund Site, Navassa, North Carolina. April.

NCDEQ. 2020. Risk Evaluation Equations and Calculations, Based on U.S. EPA Regional Screening Level Equations, May 2020.

USEPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund sites. OSWER 9355.4-24. December.

Attachment 1-2. Site-Specific Volatilization Factor Calculations

	Chemical-Specific Physical Parameters [a]							
COPC	Henry's Law Constant at Ref. Temp. (H_R) (unitless)	Diffusivity in Air (D_{air}) (cm²/sec)	Diffusivity in Water (D_{wat}) (cm²/sec)	Partition Coefficient (K_{oc}) (mL/g)	Apparent Diffusivity (D_A) (cm²/sec)	Volatile [b] (Yes/No)	Chronic Soil Volatilization Factor (VF) (m³/kg)	Subchronic Soil Volatilization Factor (VF_{sc}) (m³/kg)
PAHs								
BaP	1.9E-05	2.5E-02	6.6E-06	5.9E+05	–	No	–	–
BaP TEQ	1.9E-05	2.5E-02	6.6E-06	5.9E+05	–	No	–	–
Fluoranthene	3.6E-04	2.8E-02	7.2E-06	5.5E+04	–	No	–	–
Naphthalene	1.8E-02	6.0E-02	8.4E-06	1.5E+03	6.2E-06	Yes	3.3E+04	7.9E+03
Phenanthrene	1.7E-03	3.4E-02	6.7E-06	1.7E+04	3.2E-08	Yes	4.6E+05	1.1E+05
Pyrene	4.9E-04	2.8E-02	7.2E-06	5.4E+04	2.3E-09	Yes	1.7E+06	4.1E+05
Pesticides								
Pentachlorophenol	1.0E-06	3.0E-02	8.0E-06	5.9E+02	–	No	–	–
Dioxins/Furans								
TCDD TEQ	2.0E-03	4.7E-02	6.8E-06	2.5E+05	3.5E-09	Yes	1.4E+06	3.4E+05

Equations

Chronic Soil Volatilization Factor: Resident, Site Visitor/Trail Walker, Youth Sports Player, Trespasser, and Commercial/Industrial Worker

$$VF = Q/C_{vol} \times CF1 \times [3.14 \times D_A \times T]^{1/2} / (2 \times \rho_b \times D_A)$$

where

$$Q/C_{vol} = A \times \exp[(\ln A_s - B)^2/C]$$

$$D_A = \{[(\theta_{as}^{10/3} \times D_{air} \times H_R) + (\theta_{ws}^{10/3} \times D_{wat})] / \theta_T^2\} / \{(\rho_b \times K_{oc} \times F_{oc}) + \theta_{ws} + \theta_{as} \times H_R\}$$

Subchronic Soil Volatilization Factor: Construction Worker

$$VF_{sc} = Q/C_{sa} \times (1/F_D) \times CF1 \times (3.14 \times D_A \times T)^{1/2} / (2 \times \rho_b \times D_A)$$

where

$$Q/C_{sa} = A \times \exp[(\ln A_s - B)^2/C]$$

$$F_D = 0.1852 + (5.3537/t_c) + (-9.6318/t_c^2)$$

$$D_A = \{[(\theta_{as}^{10/3} \times D_{air} \times H_R) + (\theta_{ws}^{10/3} \times D_{wat})] / \theta_T^2\} / \{(\rho_b \times K_{oc} \times F_{oc}) + \theta_{ws} + \theta_{as} \times H_R\}$$

Chronic Soil Volatilization Parameters	**Acronym**	**Value**	**Units**	**Source**
Chronic dispersion factor for volatilies emitted from soil	Q/C_{vol}	48.6	(g/m^2-sec per kg/m^3)	calculated
Areal extent of site soil contamination	A_s	4.8	acres	site-specific
Dispersion constant A	A	12.3675	unitless	Dispersion constant for Raleigh, NC (NCDEQ 2020)
Dispersion constant B	B	18.6337	unitless	Dispersion constant for Raleigh, NC (NCDEQ 2020)
Dispersion constant C	C	212.7284	unitless	Dispersion constant for Raleigh, NC (NCDEQ 2020)
Soil dry bulk density	ρ_b	1.5	g/cm³	USEPA (2002)
Air-filled soil porosity ($\theta_{as} = \theta_T - \theta_{ws}$)	θ_{as}	0.28	cm^3/cm^3	USEPA (2002)
Water-filled porosity	θ_{ws}	0.15	cm^3/cm^3	USEPA (2002)

Attachment 1-2. Site-Specific Volatilization Factor Calculations

Total soil porosity ($\theta_T = 1 - (\rho_b/\rho_s)$)	θ_T	0.43	cm^3/cm^3	USEPA (2002)
Fraction organic carbon	F_{oc}	0.006	unitless	USEPA (2002)
Soil particle density	ρ_s	2.65	g/cm³	USEPA (2002)
Overall duration of exposure	T	8.2E+08	seconds	NCDEQ (2020) (based on 26 years of potential exposure)
Conversion factor 1	CF1	0.0001	m^2/cm^2	
Subchronic Soil Volatilization Parameters	**Acronym**	**Value**	**Units**	**Source**
Subchronic dispersion factor for volatilies emitted from soil	Q/C_{sa}	11.27	(g/m^2-sec per kg/m^3)	calculated
Areal extent of site soil contamination requiring construction	A_s	1.8	acres	site-specific
Dispersion constant A	A	2.4538	unitless	USEPA (2002)
Dispersion constant B	B	17.5660	unitless	USEPA (2002)
Dispersion constant C	C	189.0426	unitless	USEPA (2002)
Soil dry bulk density	ρ_b	1.5	g/cm³	USEPA (2002)
Air-filled soil porosity ($\theta_{as} = \theta_T - \theta_{ws}$)	θ_{as}	0.28	cm^3/cm^3	USEPA (2002)
Water-filled porosity	θ_{ws}	0.15	cm^3/cm^3	USEPA (2002)
Total soil porosity ($\theta_T = 1 - (\rho_b/\rho_s)$)	θ_T	0.43	cm^3/cm^3	USEPA (2002)
Soil particle density	ρ_s	2.65	g/cm³	USEPA (2002)
Fraction organic carbon	F_{oc}	0.006	unitless	USEPA (2002)
Dispersion correction factor	F_D	0.186	unitless	calculated
$F_D = 0.1852 + (5.3537/t_c) + (-9.6318/t_c^2)$				
Exposure duration	ED	1	year	EarthCon (2019)
Weeks worked during construction	EW	50	weeks/year	BPJ; site-specific
Duration of construction	t_c	8,400	hours	calculated
t_c = ED x EW x 7 days/wk x 24 hrs/day				
Overall duration of construction	T	3.0E+07	seconds	calculated
T = ED x EW x 7 days/wk x 24 hrs/day x 3,600 sec/hr				
Conversion factor 1	CF1	0.0001	cm^2/m^2	

Notes:

[a] The chemical-specific physical parameters were sourced from USEPA (2021) where available. The chemical-specific physical parameters for phenanthrene were soured from RAIS (2021). The chemical-specific parameters for benzo(a)pyrene are presented for BaP TEQ and 2,3,7,8-tetrachlorodibenzo-p-dioxin are presented for TCDD TEQ.

[b] The volatilization factor was only calculated for constituents that USEPA (2021) considers to be sufficiently volatile.

References:

EarthCon. 2019. Human Health Risk Assessment, Kerr-McGee Chemical Corp - Navassa Superfund Site, Navassa, North Carolina. April.
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RAIS. 2021. RAIS Toxicty Values and Physical Parameters Search. Available at: https://rais.ornl.gov/cgi-bin/tools/TOX_search?select=chemspef.
USEPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. December.
USEPA. 2021. Chemical Specific Parameter Table, May 2021. Available at: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables