5 REMEDIAL INVESTIGATION TASKS

Several steps are needed to accomplish the RI. These steps are presented and discussed below.

5.1 PROJECT PLANNING

The project plans for the RI, as outlined in these management plans, will be implemented once finalized. Revisions will be updated as necessary and will go through appropriate review by oversight agencies.

5.2 SAMPLE COLLECTION AND ANALYSIS

The field investigation at the former Rayonier Mill Site for the upland environment will be implemented as detailed in the SAP (Volume II).

5.3 DATA VALIDATION AND EVALUATION

Several phases of data evaluation must be completed before the results of the RI can be used to determine the former Rayonier Mill Site characteristics and the associated human health and environmental risks. Initially, field analytical data must be validated and reviewed for compliance with quality control criteria. The data are then interpreted for chemical sources, fate and transport, and risks.

5.3.1 DATA VALIDATION

The analytical data generated during the sampling and laboratory analyses will be used for site characterization and risk assessment (RA). Data quality objectives are detailed in the QAPP (Volume III).

5.3.2 DATA INTERPRETAION

Data sets collected are statistically summarized and reported for further interpretation. Methods for specific analyses and inferences are detailed in the SAP (Volume II).

5.4 ASSESSMENT OF RISKS

RA is a procedure used to estimate the types and probabilities of adverse effects that may result from chemicals released into the environment. This section describes the approaches to human health and ecological risks at the Rayonier facility. Because the Rayonier facility is being evaluated pursuant to a deferral agreement, the RA guidance under MTCA is the preferred approach. However, there are certain categories of human and ecological receptors that cannot be readily evaluated by strict adherence to MTCA. Consequently, both the human health and ecological RAs for the Rayonier facility are a blend of the specific guidance provided under MTCA and the additional guidance provided by EPA. The approach to human health risk assessment is described in Section 5.4.1 and that for ecological risk is described in Section 5.4.2.

5.4.1 HUMAN HEALTH RISK ANALYSIS

RA is a useful tool for evaluating potential hazards to humans and for guiding the cleanup process at contaminated sites. RA can greatly increase the efficiency of a given site cleanup by optimizing the type and amount of data collected, focusing the cleanup in specific areas and reducing the area of remediation. The RA process involves using available information to clean a site to a protective standard. Section 5.4.1.1 below is a general overview of the various components of a risk assessment and how they are integrated to make judgments concerning potential site-specific impacts to human health or to calculate site-specific cleanup levels. Subsequent sections provide descriptions of how the risk assessment process will be implemented to evaluate potential health risks associated with on-site soils (Section 5.4.1.2) and off-site residential soils.

5.4.1.1 Overview of Health Risk Assessment

Both EPA and Ecology provide guidance on the RA process. The two procedures are based on the same concepts and calculations, but differ fundamentally in how the risk assessment results are presented. EPA provides the more general guidance, and is based on providing a single estimate of risk that is summed across multiple chemicals and pathways of exposure. Ecology's approach focuses on how cleanup levels can be calculated for individual chemicals and exposure media (e.g., soils). EPA's general approach is described below to provide an overview of the fundamentals of risk assessment, which generally involves four components: (1) hazard identification and data evaluation, (2) exposure assessment, (3) toxicity assessment, and (4) risk characterization. Following the description of EPA's general approach, Ecology's approach for calculating cleanup levels for various kinds of sites will be described.

5.4.1.1.1 Hazard Identification

The hazard identification process involves a review of historical activities at a site, as well as current and future uses in order to identify areas of concern and potentially exposed people. During the hazard identification process, COPCs are determined based on the analysis of sampling results. Sample results are contrasted against established regulatory standards in a process referred to as screening. Chemicals that exceed their respective screening values are retained for further consideration. Chemicals that do not exceed their screening values may be eliminated from further consideration; however, it may be necessary to collect additional samples before a chemical can be ruled out as a COPC. Chemicals for which there are no established screening values may also be retained for further analysis, unless it can be demonstrated that these chemicals pose an insignificant human health risk.

5.4.1.1.2 Exposure Assessment

Exposure assessment is an estimate of a COPC's magnitude, frequency, duration, and route of exposure at a given location. The chemical exposure for a given population depends on the chemical concentration in the various media at a site, the amount of time spent at a site, and the behavior patterns of the exposed population. For instance, children living and playing near a hazardous site will have different exposure patterns than construction workers at the same location. For an exposure assessment, each population (e.g., children or industrial workers) should be evaluated individually. Physical characteristics of a site, such as the type of ground surface and the depth to groundwater, can impact the magnitude of the exposure.

People can be exposed to chemicals through a number of different pathways. According to EPA (1989), for a pathway to be considered complete, it must consist of four necessary components: (1) a source and mechanism of chemical release, (2) an environmental transport medium (e.g., air and water), (3) a point of potential contact with the impacted medium (referred to as an exposure point), and (4) an exposure route (e.g., inhalation or ingestion) at the contact point.

A CSM is a commonly used tool for summarizing potential exposure pathways at a given site. The CSM is a flow chart diagram that relates the exposure source, the transport pathway, and the receptor population. Among the more common exposure pathways are ingestion of water, inhalation of airborne dust, ingestion of soil, and dermal contact with soil. At many sites, however, less obvious pathways must also be considered. For instance, if a site includes offshore lake or marine sediment, people could be exposed to chemicals in this media indirectly by consuming fish with elevated chemical concentrations in their tissue. Once all of the relevant exposure pathways have been considered, a total exposure, referred to as a reasonable maximum exposure (RME), can be calculated for people at a given site by summing the chemical intake associated with each pathway.

Chemical intake can be quantified and expressed as a chronic daily intake by using the following general equation:

$$\text{Intake} = \frac{C \times CR \times ED \times EF \times F_s \times F_{abs}}{BW \times AT}$$

where:

Intake	=	Expressed as a dose (mg chemical/kg body weight per day).
C	=	Exposure point concentration [expressed a concentration in a specific medium such as soils (mg/kg dw), water (mg/L), fish (mg/kg ww)]

CR	=	Contact rate; the amount of contaminant medium contacted per unit time or event; this parameter may be a soil, sediment, or fish ingestion rate (for ingestion pathways (mg/day), an inhalation rate (m^3/day), or a skin contact rate (mg/cm^2 skin) for dermal pathways.
EF	=	Exposure frequency (number of days per year)
ED	=	Exposure duration (years of exposure)
BW	=	Body weight over the exposure period (kg)
AT	=	Averaging time; period over which exposure is averaged (days); for carcinogens, exposure is averaged over a 70-year lifetime; for noncarcinogens, exposure is averaged over the exposure duration.
F_s	=	Fraction of exposure media contact contributed by the source (unitless)
F_{abs}	=	Fraction of chemical absorbed.

5.4.1.1.3 Toxicity Assessment

The relationship between exposure and adverse health effects is established through the toxicity assessment. Information regarding toxic effects of chemicals to humans is developed from a number of sources. If adequate human data are available, this information is used as the basis for the toxicity criteria. When direct human data are inadequate, toxicity values are developed by interpreting animal studies. If the toxicological data are not available for a particular exposure route, available toxicity information from another exposure route is adjusted for application to the route of interest. In general, the objective of the toxicity assessment is to establish a dose-response relationship between the amount of chemical intake and the severity of toxic effects. The approach for calculating a chemical's relative toxicity varies, depending on whether a chemical is considered a cancer-causing agent (carcinogen) or a systemic toxicant (noncarcinogen).

5.4.1.1.3.1 Noncarcinogens

For noncarcinogens, the outcome of a toxicity assessment is the development of a reference dose (RfD) or a reference concentration (RfC), which is considered a safe exposure level for an upper percentage of a given population. The study on the most sensitive population or species (the population showing a toxic effect at the lowest dose) is the basis for developing RfDs. The effect characterized by the "lowest-observed-adverse-effect level" (LOAEL) is the lowest dose at which an adverse effect was observed. In addition, EPA identifies the experimental exposure level representing the highest level at which no adverse effects (including the critical toxic effect) were observed. The highest "no-observed-adverse-effect level" (NOAEL) or the LOAEL are used to develop RfDs.

RfDs are calculated as the NOAEL or LOAEL divided by the product of the appropriate uncertainty factors (UFs) and modifying factors (MFs). Uncertainty factors are included to account for the uncertainty that may be associated with various components of the RfD development process, including the following extrapolations: from animal data to humans, from high-dose to low-dose exposures, from one exposure route to another, from short-term to long-term effects, and/or from less-sensitive to more-sensitive individuals in the population. Depending upon the study on which the RfD was based, the UF may range from less than 10 to 10,000. The MF is an additional UF ranging from less than 0 to 10. The purpose of the MF is to account for uncertainties not addressed by the other categories mentioned above, or to account for limitations in the overall database (e.g., number of studies or number of species tested). The use of UFs and MFs generally results in toxicity values that are unlikely to underestimate risks.

5.4.1.1.3.2 Carcinogens

For carcinogens, EPA generally assumes that effects on a single cell can evoke changes that may lead to the onset of disease; therefore, no dose is considered risk-free. Carcinogens are categorized into weight-of-evidence categories that represent the amount of evidence available to suggest their carcinogenicity. The weight-of-evidence classification is based on EPA's Proposed Guidelines for Carcinogen Risk Assessment (EPA, 1996) as described in Table 5-1.

Table 5-1. Weight of Evidence Classification for Carcinogenic Substances.

Weight-of-Evidence Category	Description
A	Human carcinogen.
B1 or B2	Probable human carcinogen. B1 indicates that limited human data are available. B2 indicates sufficient evidence in animals and inadequate or no evidence in humans.
C	Possible human carcinogen.
D	Not classifiable as to human carcinogenicity.
E	Evidence of noncarcinogenicity for humans.

The toxicity criteria that EPA has developed to quantify carcinogenic dose-response relationship are called cancer slope factors (CSFs). A CSF is a plausible, upper-bound estimate of the probability of developing cancer per unit intake of a chemical over a lifetime. At low levels of exposure, the probability of cancer cannot be measured, but must be extrapolated from higher dosages. In order to observe a quantifiable effect on the exposed population, animals typically are exposed to concentrations that are orders of magnitude greater than what is likely to be encountered by human populations. EPA has calculated CSFs for many potential carcinogens in classes A, B1, and B2. For class C chemicals, quantitative estimates of CSFs must be performed on a case-by-case basis.

For chemicals sharing similar properties, such as CDDs and CDFs, EPA has developed toxicity values based on relative risk. For CDDs and CDFs, TEFs have been assigned to all CDDs and CDFs based on their cancer potency relative to 2,3,7,8-TCDD, the most toxic and widely studied chemical in this class of compounds. The magnitude of the TEFs is determined both by their structure (i.e., the number and position of the halogen atoms on the dioxin-like compound) and by in vivo and in vitro toxicity test results. A similar TEF approach is commonly used for carcinogenic PAHs with toxicity values expressed relative to benzo(a)pyrene.

5.4.1.1.3.3 Sources of Toxicity Data

EPA maintains and updates a list of toxicity values for several hundred chemicals in the Integrated Risk Information System (IRIS) catalogue. Additional sources for toxicity values is the EPA's Health Effects Summary Tables (HEAST), which is updated quarterly, and EPA's National Center for Environmental Assessment. Both of these sources summarize interim and final RfDs and CSFs and other toxicity information for specified chemicals. Ecology provides its own summary tables of toxicity values in its Cleanup Levels and Risk Calculations (CLARC) publication. Many of the values presented in the CLARC tables are from IRIS and HEAST.

5.4.1.1.4 Risk Characterization

Risk characterization is the final step of the RA process, which involves calculating risks to exposed individuals by relating the chemical intake calculated in the exposure assessment to the dose-response values determined in the toxicity assessment. Separate risk characterizations are conducted by noncarcinogens and carcinogens.

5.4.1.1.4.1 Noncarcinogenic Risk

For noncarcinogens, potential health threats are estimated by comparing the estimated average daily exposure with the RFD value by calculating a hazard quotient (HQ):

$$\text{Hazard Quotient} = \frac{\text{Intake}}{\text{RfD}}$$

where:

Intake	=	Chronic daily intake, averaged over the exposure duration (mg/kg-day)
RfD	=	Reference dose (mg/kg-day).

If a person's average exposure is less than the RfD (i.e., if the hazard quotient is lower than one), the chemical is considered unlikely to pose a significant noncarcinogenic health hazard to individuals under the given exposure conditions. Unlike carcinogenic risk estimates, a hazard quotient is not expressed as a probability. Therefore, while both cancer and noncancer risk characterizations indicate a relative potential for adverse effects to occur from exposure to a chemical, a noncancer health threat estimate is not directly comparable with a cancer risk estimate.

If more than one noncarcinogen or pathway is evaluated, the hazard quotients for each chemical and each pathway are summed to determine whether exposure to a combination of pathways and chemicals poses a health concern. This sum of the hazard quotients is known as a hazard index (HI). Where HIs exceed a ratio of 1.0, noncarcinogenic COPCs are segregated according to target organ, effect, and mechanism of action.

5.4.1.1.4.2 Carcinogenic Risk

In the risk characterization, carcinogenic risk is estimated as the incremental probability of an individual developing cancer over a lifetime as a result of a chemical exposure.

Carcinogenic risks are evaluated by multiplying the estimated average exposure rate (i.e., the lifetime average daily intake calculated in the exposure assessment) by the chemical's CSF.

$$\text{Risk} = \text{CSF} \times \text{Intake}$$

where:

Risk = Chemical-specific probability of cancer over a 70-year lifetime of exposure

Intake = Chronic daily intake, averaged over a 70-year lifetime (mg/kg-day)

CSF = Cancer slope factor (mg/kg-day).

The CSF converts estimated daily intakes averaged over a lifetime to incremental risk of an individual developing cancer. Because cancer risks are averaged over a person's lifetime, longer-term exposure to a carcinogen will result in higher risks than shorter-term exposure to the same carcinogen, if all other exposure assumptions are constant. Theoretical risks associated with low levels of exposure in humans are assumed to be directly related to an observed cancer incidence in animals associated with high levels of exposure. According to EPA (1989), this approach is appropriate for theoretical upper bound cancer risks of less than 1 × 10-2.

The total risk to a given population at a site can be expressed as the sum of the individual risk for each chemical associated with each exposure pathway. For carcinogens, it is assumed that simultaneous exposures to multiple chemicals are additive, unless information is available that suggests interactions such as antagonism or synergism. Thus, the result of the assessment will be an upper-bound estimate of the total carcinogenic risk, which can be compared to EPA's risk range of 10-6 to 10-4. In general, risks less than 10-6 are considered de-minimis and do not require a cleanup action. Site-management and clean up decisions are made on a case-by-case basis when risks in the range of 10-6 to 10-4. Risks greater than 10-4 almost always require a site-management action.

5.4.1.1.5 Risk Assessment in the Model Toxics Control Act

Ecology's approach focuses on how cleanup levels can be calculated for individual chemicals and exposure media (e.g., soils) by assuming a fixed level of risk (e.g., 10^{-5} cancer risk), re-arranging the general algebraic equation for calculating risk, and solving the expression for the corresponding chemical concentration in an exposure medium (e.g., soils). Ecology's approach is summarized in the MTCA (WAC 173-340-708) that was revised in February 2001.

Under MTCA, three approaches for determining cleanup levels are described, and are referred to as Method A, Method B, and Method C. Method A is the most basic approach for establishing cleanup levels at a site. Method A is applicable to sites meeting specific criteria: the former Rayonier Mill Site must meet routine cleanup actions as defined in WAC 173-340-130; there are few hazardous substances present; and numerical cleanup values are available for the hazardous substances at the former Rayonier Mill Site, as provided in WAC 173-340-720, 740, or 745. Method B is a cleanup approach that can be applied to all sites and involves the calculation of cleanup levels using RA principles. Under Method B, Ecology allows for the use of either a standard approach, or one using modified assumptions. Under the standard approach, default assumptions are used to calculate cleanup levels, whereas under the modified approach, site-specific information can be incorporated to calculate cleanup levels that are more realistic for a given site.

Method C can be used to calculate cleanup levels that are protective of human health and the environment under certain site uses and conditions, including sites where usage is limited to industrial activities. Method C cleanup values can be applied to multiple environmental media (i.e., soil, groundwater, and air), however, each medium must be evaluated separately. In other words, even if the soil at a site is to be used for industrial activity, the groundwater cleanup level does not automatically meet Method C criteria.

5.4.1.2 On-site Soils

Due to the long history of industrial activity at the former Rayonier Mill Site, future uses will likely be maintained for industrial activities. The conceptual site model for on-site soils is presented in Section 3.3 above. A summary of the relevant receptor population and exposure pathways is provided in Table 5-2. In addition, potential Native American uses of the mill site will be evaluated. It is assumed, therefore, that on-site workers are the receptors of concern. Soils at the former Rayonier Mill Site will, therefore, be screened against industrial cleanup standards under MTCA Method C for all COPCs. The MTCA Method C industrial cleanup standard for direct contact with soil (ingestion only) assumes an adult will be exposed to soil-borne chemicals for a period of 20 years, ingest soil at a rate of 50 mg/d, and have an exposure frequency of 146 d/y. A target hazard quotient of 1.0 and the target carcinogenic risk of 1 x 10 E-05 is used to calculate Method C cleanup levels. If a use other than industrial is identified during the RI process, than a site-specific evaluation for those areas may be performed.

5.4.1.3 Residential Soils

The conceptual site model for off-site soils is presented in Section 3.3 above. A summary of the relevant receptor population and exposure pathways is provided in Table 5-2. Soil concentrations found on residential soils will be evaluated based on site-specific evaluations of the data set and the resulting risks, as estimated through MTCA Method B. Site-specific analyses will not only allow for better estimates of overall risks, but will allow for better communications with the community and more latitude in the development of remedial alternatives, if warranted.

5.4.2 ECOLOGICAL RISK ANALYSES

In addition to safeguarding long-term human health, RIs are also required to evaluate environmental health. The approach for this evaluation is discussed below for soils and sediments.

5.4.2.1 Upland Soils

The on-site soil ecological RA will be conducted following recently promulgated MTCA terrestrial ecological evaluation procedures (WAC 173-340-7490). The framework for the terrestrial ecological evaluation procedures (Figure 5-1) consists of three tiers. Tier 1 (exclusions from a terrestrial ecological evaluation) consists of a set of simple criteria that are used to determine if the former Rayonier Mill Site can be excluded from further evaluation. If the former Rayonier Mill Site requires further evaluation, criteria are provided to determine if it should be evaluated using either Tier 2 or Tier 3 procedures. The Tier 2 evaluation (simplified terrestrial ecological evaluation) consists of an evaluation of the extent of exposure, an exposure pathway analysis, and a comparison of chemical concentrations in site soil to screening concentrations protective of plants and/or animals. If the former Rayonier Mill Site passes the Tier 2 evaluation, no further evaluation will be needed. If the former Rayonier Mill Site fails the Tier 2 evaluation, it can either proceed toward a cleanup action or a Tier 3 evaluation. The Tier 3 evaluation (site-specific terrestrial ecological evaluation) is a detailed risk assessment that consists

Table 5-2. Human Health Exposure Pathways and Potentially Contaminated Media

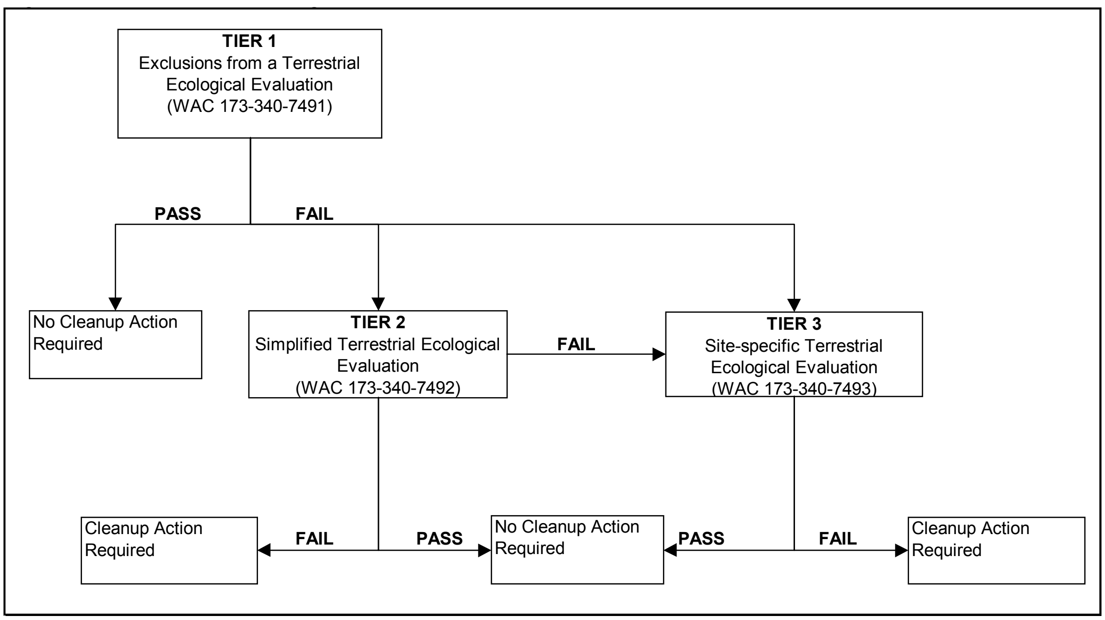
Location	Receptor	Route of Exposure	Air[a]	Soils	Surface Water[b]	Terrestrial Biota	Sediments	Sediment Porewater	Aquatic Biota
On-Site	Workers[c]	Respiration	●						
		Ingestion		●	○	○			
		Dermal Absorption		●	○				
	Native American	Respiration							
		Ingestion		●	○	○	○		
		Dermal Absorption		●	○				
	Future Residents[d]	Respiration	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
		Ingestion	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
		Dermal Absorption	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Off-Site	Residents	Respiration	●						
		Ingestion		●	○		○	○	●
		Dermal Absorption		●	○		○	○	
	Recreational Anglers	Respiration							
		Ingestion			○		○	○	●
		Dermal Absorption			○		○	○	
	Subsistence Anglers	Respiration							
		Ingestion			○		○	○	●
		Dermal Absorption			○		○	○	

[a] Inhalation of fugitive dust associated with historical stack emissions and wet and dry deposition to local soils.
[b] Includes indirect exposure via ground water that may be discharged to Ennis Creek or Port Angeles Harbor.
[c] MTCA Method C.
[d] Future residential scenario is not applicable (N/A) for on-site land use.

● = Primary evaluation pathway
○ = Secondary evaluation pathway

of three steps: problem formulation, selection of appropriate methods for assessing risks, and the characterization of adverse ecological effects. Problem formulation defines the focus of the evaluation by selecting COCs, identifying complete exposure pathways and ecological receptors, and performing a toxicity assessment that identifies a dose-response relationship between chemical uptake and possible adverse effects on receptors of concern. Various assessment methods are available for a Tier 3 evaluation (e.g., soil bioassays, wildlife exposure models, and site-specific field studies), and a method is selected based on site-specific conditions.

Figure 5-1. MTCA Terrestrial Ecological Evaluation Framework



If the former Rayonier Mill Site meets any of the following Tier 1 criteria, no further evaluation is required:

- All soil with hazardous substances is, or will be, located below the point of compliance (the standard point of compliance is 15 feet; a conditional point of compliance may be established as the biologically active zone [assumed to be a depth of 6 feet] where institutional controls prevent excavation of deeper soils).
- All soil contaminated with hazardous substances is, or will be, covered by buildings, paved roads, pavement, or other physical barriers that will prevent ecological receptors from being exposed to the soil contamination.
- For sites contaminated with CDDs/CDFs, PCB mixtures, DDT/DDE/DDD, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor/heptachlor epoxide, benzene hexachloride, toxaphene, hexachlorobenzene, pentachlorophenol, or pentachlorobenzene, there is less than ¼-acre of contiguous undeveloped land on

or within 500 feet of any area of the former Rayonier Mill Site affected by these hazardous substances.

At the former Rayonier Mill Site, hazardous substances do occur at depths less than 15 feet, areas exist where ecological receptors may become exposed to contaminated soils (e.g., the riparian habitat bordering Ennis Creek), and there is more than ¼-acre of contiguous undeveloped land on site. The former Rayonier Mill Site must, therefore proceed to either a Tier 2 or Tier 3 evaluation.

If any one of the following conditions is present, a Tier 3 evaluation should be conducted:

- The former Rayonier Mill Site is located on, or directly next to, an area where management or land-use plans will remain in place or will restore native or seminative vegetation.
- The former Rayonier Mill Site is used by a threatened or endangered species, a wildlife species classified by WDFW as a priority species or species of concern under Title 77 RCW, or a plant species classified by the WDNR Natural Heritage Program as endangered, threatened, or sensitive under Title 79 RCW.
- The former Rayonier Mill Site is located on a property that contains at least 10 acres of native vegetation within 500 feet of the site, not including vegetation beyond the property boundaries.
- Ecology determines that the former Rayonier Mill Site may present a risk to significant wildlife populations.

The former Rayonier Mill Site is currently zoned for industrial land use and is bounded by residential, commercial, and industrial properties. Land next to a sewer line entering the former Rayonier Mill Site and continuing along the southern bluff to the sewage treatment plant is designated as park-land. Environmentally sensitive areas as defined in the Port Angeles Municipal Code include streams, ravines, and marine bluffs that occur on the site and require the maintenance of undisturbed vegetation. Section 2.2.6.1 of this report describes the biological setting and concludes that no federal or state listed species will significantly utilize the upland portion of the former Rayonier Mill Site for food, cover, or water. The former Rayonier Mill Site contains more than 10 acres of native vegetation along the Ennis Creek corridor and the site entrance. As more than 10 acres of vegetation occur on the former Rayonier Mill Site, a Tier 3, site-specific, terrestrial ecological evaluation will be performed using on-site soils.

The MTCA terrestrial ecological evaluation procedures have different goals for sites, depending on whether there is unrestricted land use or industrial/commercial land use. For industrial/commercial sites, , the goal of the terrestrial ecological evaluation is protection of terrestrial wildlife, while for unrestricted land use, the goal is the protection of wildlife, plants, and soil invertebrates. Although the former Rayonier Mill site is predominantly zoned heavy industrial, much of the southern portion of the site is undeveloped with a zoning designation of public buildings and parks. The Port Angeles Municipal Code states that land zoned for public buildings and parks is commonly used as green belts. In addition, local ordinances require that undisturbed vegetation be maintained in environmentally sensitive areas (e.g., streams, marine bluffs, and ravines). Therefore, the goal of the ecological assessment in the undeveloped portion of the site will be the protection of wildlife, plants, and soil invertebrates. Areas of the developed portion of the site that do not prohibit ecological exposure to soil-borne contaminants will be assessed with the goal of protecting wildlife. The former Rayonier Mill Site contains both undeveloped and developed areas. The undeveloped areas contain habitat of sufficient quality to provide a significant potential source of exposure of plants, soil biota, and wildlife to soil-borne chemicals. Figure 5-2 shows that these undeveloped areas include uplands located along the coastal bluffs east and west of the pier, uplands at the entrance to the former Rayonier Mill Site, and the Ennis Creek riparian corridor. The developed portion of the site is a mixture of cover types ranging from concrete on grade to isolated open soil areas. A site visit identified areas where wildlife exposure to soil-borne chemicals was possible and to identify areas that support sufficient plant and soil invertebrate populations to act as a food source for wildlife. The approach and results of this survey are provided in Appendix A.

The first step in the problem formulation for the Tier 3 terrestrial ecological evaluation is to select ecological COPCs. Ecological COPCs were primarily selected by comparing the maximum detected concentration of chemicals in soil samples collected by EPA during the ESI (E&E 1998) to the ecological soil indicator concentrations provided in MTCA. The lowest soil indicator concentrations were used in the comparisons that are protective of plants, soil biota, and wildlife. The maximum detected concentration must also exceed natural background to be selected as a COPC. Results are presented in Table 5-3 for detected chemicals having a soil indicator concentration and show 19 chemicals exceeding the soil indicator concentrations and background (i.e., dioxins/furans, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, zinc, Aroclor 1260, and pentachlorophenol). Pentachlorophenol was assessed further to confirm its selection as an ecological COPC. MTCA allows the use of either the maximum detected concentration or the 95 percent upper confidence limit of the site data in making comparisons to the soil indicator concentrations. The 95 percent upper confidence limit for pentachorphenol was calculated to be 1.24 mg/kg which is less than the soil indicator concentration of 3.0 mg/kg. Therefore, pentachlorophenol was not selected as an ecological COPC. PCBs are not associated with pulp mill stack emissions, so would only be an ecological COPC on the industrialized portion of the mill site where other potential sources of PCBs exist.

Table 5-3. Comparison of EPA's ESI Soil Data to Background and Ecological Soil Indicator Concentrations (chemical concentrations expressed in mg/kg). (Part 1 of 3)

Analyte	# of Samples	# Rejected	# Undetected	Detection Frequency	Detection Limit Range		Range of Detections		Background [a]	Soil Indicator Concentration [b]
					Minimum	Maximum	Minimum	Maximum		
Dioxins and Furans										
1,2,3,4,6,7,8-HpCDD	31	--	5	84%	5.70E-07	2.10E-06	2.70E-06	1.20E-01	--	2.00E-06
1,2,3,4,6,7,8-HpCDF	31	--	9	71%	1.70E-07	2.30E-06	2.90E-06	1.30E-02	--	2.00E-06
1,2,3,4,7,8,9-HpCDF	31	--	16	48%	1.40E-07	1.40E-06	5.20E-06	1.50E-03	--	2.00E-06
1,2,3,4,7,8-HxCDD	31	--	11	65%	1.10E-07	2.30E-06	3.30E-06	1.40E-03	--	2.00E-06
1,2,3,4,7,8-HxCDF	31	--	14	55%	1.60E-07	2.20E-06	2.40E-06	6.90E-04	--	2.00E-06
1,2,3,6,7,8-HxCDD	31	--	10	68%	1.90E-07	2.20E-06	5.60E-06	3.50E-03	--	2.00E-06
1,2,3,6,7,8-HxCDF	31	--	10	68%	1.90E-07	2.20E-06	2.80E-06	3.30E-04	--	2.00E-06
1,2,3,7,8,9-HxCDD	31	--	10	68%	1.90E-07	2.20E-06	5.50E-06	2.80E-03	--	2.00E-06
1,2,3,7,8,9-HxCDF	31	--	21	32%	1.30E-07	1.90E-06	3.90E-06	2.70E-05	--	2.00E-06
1,2,3,7,8-PeCDD	31	--	12	61%	1.60E-07	2.10E-06	3.20E-06	5.80E-04	--	2.00E-06
1,2,3,7,8-PeCDF	31	--	20	35%	1.70E-07	2.20E-04	2.60E-06	8.80E-05	--	2.00E-06
2,3,4,6,7,8-HxCDF	31	--	16	48%	1.20E-07	1.90E-06	3.00E-06	1.80E-04	--	2.00E-06
2,3,4,7,8-PeCDF	31	--	12	61%	2.00E-07	2.20E-06	2.70E-06	2.50E-04	--	2.00E-06
2,3,7,8-TCDD	31	--	12	61%	1.20E-07	8.50E-07	8.10E-07	7.40E-05	--	2.00E-06
2,3,7,8-TCDF	31	--	10	68%	1.50E-07	2.80E-06	6.30E-07	1.40E-04	--	2.00E-06
OCDD	31	--	1	97%	1.50E-06	1.50E-06	6.70E-06	5.30E-01	--	2.00E-06
OCDF	31	--	11	65%	6.20E-07	4.30E-06	8.30E-06	6.80E-02	--	2.00E-06
Inorganics										
Aluminum	137	--	--	100%	--	--	7.03E+02	3.23E+04	3.26E+04	5.00E+01
Antimony	137	13	100	19%	9.50E-01	2.57E+01	9.30E-01	9.40E+01	--	5.00E+00
Arsenic	137	--	23	83%	8.70E-01	9.70E+00	8.90E-01	2.60E+02	7.00E+00	7.00E+00
Barium	137	--	--	100%	--	--	1.24E+01	6.73E+02	--	1.02E+02
Beryllium	137	--	15	89%	2.00E-02	3.40E-01	4.00E-02	5.60E-01	6.00E-01	1.00E+01

Table 5-3. Comparison of EPA's ESI Soil Data to Background and Ecological Soil Indicator Concentrations (chemical concentrations expressed in mg/kg). (Part 2 of 3)

Analyte	# of Samples	# Rejected	# Undetected	Detection Frequency	Detection Limit Range		Range of Detections		Background [a]	Soil Indicator Concentration [b]
					Minimum	Maximum	Minimum	Maximum		
Inorganics, *continued*										
Cadmium	137	--	66	52%	1.00E-02	4.40E+00	8.00E-02	1.40E+02	1.00E+00	4.00E+00
Chromium	137	--	1	99%	2.56E+01	2.56E+01	7.90E+00	3.57E+02	4.80E+01	4.20E+01
Cobalt	137	--	--	100%	--	--	1.00E+00	3.97E+01	--	2.00E+01
Copper	137	--	--	100%	--	--	1.53E+01	9.37E+03	3.60E+01	5.00E+01
Lead	137	--	1	99%	2.60E+00	2.60E+00	1.40E+00	8.61E+03	2.40E+01	5.00E+01
Manganese	137	--	--	100%	--	--	1.37E+01	4.90E+03	1.20E+03	1.10E+03
Mercury	137	--	85	38%	5.00E-02	4.70E-01	6.00E-02	6.60E+00	7.00E-02	1.00E-01
Nickel	137	--	4	97%	2.60E+00	3.02E+01	8.90E+00	1.53E+02	4.80E+01	3.00E+01
Selenium	137	--	124	9%	4.50E-01	6.40E+00	5.30E-01	5.40E+00	--	1.00E+00
Silver	137	--	17	88%	1.70E-01	1.30E+00	1.80E-01	4.88E+01	--	2.00E+00
Thallium	137	--	125	9%	5.70E-01	4.70E+00	5.90E-01	7.00E+00	--	1.00E+00
Vanadium	137	--	--	100%	--	--	6.20E+00	1.80E+02	--	2.00E+00
Zinc	137	--	--	100%	--	--	9.30E+00	4.31E+03	8.50E+01	8.60E+01
Pesticides and PCBs										
4,4'-DDD	141	--	136	4%	2.70E-03	3.40E-02	3.70E-04	3.80E-03	--	7.50E-01
4,4'-DDE	141	--	104	26%	3.40E-03	4.90E-02	2.90E-04	3.40E-02	--	7.50E-01
4,4'-DDT	141	--	110	22%	5.30E-04	6.50E-02	4.70E-04	4.60E-02	--	7.50E-01
Aldrin	141	--	114	19%	1.80E-03	2.50E-02	2.00E-04	2.20E-02	--	1.00E-01
alpha-BHC	141	--	134	5%	1.80E-03	2.50E-02	2.10E-04	3.90E-04	--	6.00E+00
alpha-Chlordane	141	--	132	6%	5.10E-04	2.50E-02	7.40E-04	1.30E-02	--	1.00E+00
Aroclor 1254	141	--	139	1%	3.40E-02	4.90E-01	1.20E-02	7.70E-02	--	6.50E-01
Aroclor 1260	141	--	109	23%	3.40E-02	4.90E-01	8.90E-03	4.80E+00	--	6.50E-01
beta-BHC	141	--	80	43%	1.80E-03	1.50E-02	2.30E-04	2.30E-01	--	6.00E+00

Table 5-3. Comparison of EPA's ESI Soil Data to Background and Ecological Soil Indicator Concentrations (chemical concentrations expressed in mg/kg). (Part 3 of 3)

Analyte	# of Samples	# Rejected	# Undetected	Detection Frequency	Detection Limit Range		Range of Detections		Background [a]	Soil Indicator Concentration [b]
					Minimum	Maximum	Minimum	Maximum		
Pesticides and PCBs, *continued*										
delta-BHC	141	--	138	2%	1.80E-03	2.50E-02	2.00E-03	2.80E-03	--	6.00E+00
Dieldrin	141	--	120	15%	2.70E-03	4.90E-02	3.90E-04	4.40E-02	--	7.00E-02
Endrin	141	--	133	6%	3.40E-03	5.00E-02	4.40E-04	2.10E-02	--	2.00E-01
gamma-BHC	141	--	135	4%	1.80E-03	1.50E-02	4.10E-04	4.30E-02	--	6.00E+00
gamma-Chlordane	141	--	107	24%	1.80E-03	2.50E-02	2.30E-04	1.60E-02	--	1.00E+00
Heptachlor	141	--	128	9%	1.80E-03	9.40E-03	3.60E-04	3.00E-02	--	4.00E-01
Heptachlor epoxide	141	--	104	26%	8.10E-04	2.50E-02	3.40E-04	3.70E-02	--	4.00E-01
Semivolatile Compounds										
2,4-Dichlorophenol	137	--	134	2%	3.40E-01	3.00E+00	9.50E-02	8.20E-01	--	1.00E+01
4-Nitrophenol	137	--	136	1%	3.50E-01	7.50E+00	1.10E-01	1.10E-01	--	7.00E+00
Acenaphthene	137	--	116	15%	3.40E-01	3.00E+00	4.70E-02	1.30E+00	--	2.00E+01
Benzo(a)pyrene	137	13	99	20%	3.40E-01	3.00E+00	3.80E-02	3.30E+00	--	1.20E+01
Diethyl phthalate	137	--	117	15%	3.40E-01	3.00E+00	5.70E-01	4.30E+00	--	1.00E+02
Dimethyl phthalate	137	--	108	21%	3.40E-01	3.00E+00	5.50E-02	1.10E+00	--	2.00E+02
Di-n-butyl phthalate	137	1	128	6%	3.40E-01	3.00E+00	5.90E-02	7.60E-01	--	2.00E+02
Fluorene	137	--	115	16%	3.40E-01	2.20E+00	4.40E-02	1.30E+00	--	3.00E+01
Pentachlorophenol	137	1	116	15%	8.60E-01	5.50E+00	4.30E-02	2.60E+01	--	3.00E+00
Phenol	137	--	129	6%	3.40E-01	3.00E+00	5.90E-02	6.80E-01	--	3.00E+01
Volatile Compounds										
Toluene	136	--	113	17%	1.00E-02	4.50E-01	1.00E-03	3.50E+00	--	2.00E+02

[a] Background concentrations obtained from Ecology (1994) for the Puget Sound area.

[b] Concentrations are the lowest of the ecological indicator soil concentrations from MTCA (Table 749-3) for plants, soil biota, and wildlife.

The second task under the problem formulation step of the Tier 3 terrestrial ecological evaluation is to identify complete pathways of exposure to COPCs. The conceptual site model for on-site terrestrial receptors is presented in Section 3.3 above. A summary of the relevant receptor population and exposure pathways is provided in Table 5-4. For wildlife, the primary pathways of exposure are chemicals in soil and forage. Potential routes of exposure are inhalation of fugitive dust associated with soils, dermal contact with soils, and ingestion of soils and forage. The inhalation and dermal contact routes of exposure are, however, usually of minor importance for wildlife because potential exposure via these routes is usually low relative to the ingestion route, and reliable methods for evaluating exposure and toxicity via these routes are limited. Therefore, the ingestion route of exposure will be used in this assessment. Wildlife may be exposed to soil-borne contaminants through direct ingestion of soil while foraging and grooming. Chemical migration in food chains is of particular importance for contaminants with a high potential to bioaccumulate (e.g., dioxins or PCBs). The complete pathways of chemical exposure that will be the focus of this assessment are soil-to-wildlife and soil-to-prey-to-wildlife. Plants and earthworms will be exposed to chemicals in the soil through dermal absorption and earthworms also ingest soil directly (i.e., soil and detritus) while foraging.

The third task under the problem formulation step of the Tier 3 terrestrial ecological evaluation is to identify receptors of concern that are likely to live or feed at the former Rayonier Mill Site. In the undeveloped portion of the site, grasses and earthworms are identified as receptors of concern. Grasses and earthworms are representative of plants and soil invertebrates in general, they are important food for target wildlife species, there is considerable ecotoxicity information available on them, and they are commonly referenced in MTCA. Wildlife are target receptors in both the undeveloped and developed portions of the site. Table 2-1 lists wildlife species likely to live or feed on the Rayonier site and Table 2-4 lists species of concern that inhabit the northern portion of the Olympic Peninsula. The MCTA Tier 2 and Tier 3 terrestrial ecological evaluation processes base all or part of their evaluations on wildlife exposure models for three species, the shrew (*Sorex* spp.), American robin (*Turdus migratorius*), and the vole (*Microtus* spp.).

Rayonier Mill Site

Figure 5.2
Upland and Riparian Habitat in Rayonier Site

Table 5-4. Ecological Exposure Pathways and Potentially Contaminated Media (Part 1 of 2)

Location	Receptor	Route of Exposure	Air[a]	Soils	Surface Water[b]	Terrestrial Biota	Sediments	Sediment Porewater	Aquatic Biota
On-Site	Plants[c]	Respiration							
		Ingestion							
		Dermal Absorption		●					
	Earthworms[c]	Respiration							
		Ingestion		●					
		Dermal Absorption		●					
	Shrew	Respiration	○						
		Ingestion		●	○	●			
		Dermal Absorption		○	○				
	Robin	Respiration	○						
		Ingestion		●	○	●			
		Dermal Absorption		○	○				
	Vole	Respiration	○						
		Ingestion		●	○	●			
		Dermal Absorption		○	○				
	Aquatic - Limnetic	Respiration			●				
		Ingestion							●
		Dermal Absorption			●				
	Aquatic - Benthic	Respiration						●	
		Ingestion					●		●
		Dermal Absorption						●	
Off-Site	Marine - Pelagic Biota	Respiration			●				
		Ingestion			●				●
		Dermal Absorption			●				
	Marine - Benthic Biota	Respiration						●	
		Ingestion					●	●	●
		Dermal Absorption						●	

Table 5-4. Ecological Exposure Pathways and Potentially Contaminated Media (Part 2 of 2)

Location	Receptor	Route of Exposure	Air[a]	Soils	Surface Water[b]	Terrestrial Biota	Sediments	Sediment Porewater	Aquatic Biota
	Greater Scaup	Respiration							
		Ingestion			●		●		●
		Dermal Absorption							
	Double Crested Cormorant	Respiration							
		Ingestion			●				●
		Dermal Absorption							
	Black-bellied Plover	Respiration							
		Ingestion			●		●		●
		Dermal Absorption							
	Harbor Seal	Respiration							
		Ingestion							●
		Dermal Absorption							
	Otter	Respiration							
		Ingestion			●		●		●
		Dermal Absorption							

[a] Inhalation of fugitive dust associated with past spills and historical stack emissions and wet and dry deposition to local soils.
[b] Includes indirect exposure via ground water that may be discharged to Ennis Creek or Port Angeles Harbor.
[c] These receptors will be evaluated for bioaccumulation and as vectors for chemical exposure to higher trophic levels.

● = Primary evaluation pathway.
● = Secondary evaluation pathway.

The shrew is representative of the insectivorous mammal feeding guild, the robin of the insectivorous bird feeding guild, and the vole of the herbivorous mammal feeding guild. All three species have relatively small home ranges, high soil ingestion rates, and high food ingestion rates, resulting in high exposures to soil-borne contaminants. The shrew and robin would also be highly exposed to bioaccumulative chemicals through their consumption of earthworms. The vole would similarly be exposed to contaminants taken up by its forage plants. The shrew, robin, and vole are identified as the wildlife species of concern that are representative of broader groups of wildlife. The fourth task under the problem formulation step of the Tier 3 terrestrial ecological evaluation is to identify significant adverse effects in the receptors of concern that may result from exposure to COPCs. A description of the effects of ecological COPCs on wildlife will be developed during the RI.

Risks to grasses and earthworms will be assessed by comparing chemical concentrations in soil to ecological indicator soil concentrations (MTCA Table 749-3), ecotoxicity values found in the scientific literature that are protective of plants and earthworms, and background concentrations.

The assessment method that will be used to evaluate risks to the shrew, robin, and vole is a site-specific wildlife exposure model. These models will be used to calculate risk-based soil screening levels that are concentrations below which significant adverse effects from exposure of receptors to soil-borne contaminants are not expected to occur. The models use estimates of exposure and toxicity to calculate the soil screening levels. The identical method is used in MTCA to derive the Tier 2 and Tier 3 soil screening levels and is recommended as a Tier 3 assessment method.

The formula that will be used to calculate the screening levels is as follows:

$$SSL_{hj} = (T_{hj})/[(FIR_h \times P_h \times BAF_{ij}) + (SIR_h \times RGAF_{hj})]$$

Where:

SSL_{hj} = Soil screening level for the h^{th} species and j^{th} chemical (mg/kg soil dw)

T_{hj} = Toxicity reference value for the h^{th} species and j^{th} chemical (mg/kg body weight -day)

FIR_h = Food ingestion rate for the h^{th} species (kg dry food/kg body weight – day)

P_h = Proportion of contaminated food in diet for the h^{th} species (unitless)

BAF_{ij} = Bioaccumulation factor for the i^{th} prey type and j^{th} chemical (kg soil dw/kg body weight)

SIR_h = Soil ingestion rate for the h^{th} species (kg soil dw/kg body weight – day)

$RGAF_{hj}$ = Gut absorption factor for the h^{th} species and j^{th} chemical in soil expressed relative to the gut absorption factor for the chemical in food (unitless)

Ecological toxicity reference values (T) for many of the COPCs at the former Rayonier Mill Site are provided in MTCA and will be used in this assessment if more relevant information is unavailable. Toxicity reference values for COPCs that are not provided in MTCA will be derived by using the methodology recommended in MTCA. The wildlife exposure models will use the exposure factors provided in MTCA if more current and relevant information is unavailable (Table 5-5).

Table 5-5. Wildlife Species Exposure Parameter Values

Species	Proportion of Contaminated Food in Diet (unitless) (*P*)	Food Ingestion Rate (kg dry food/kg body weight-d) (*FIR*)	Soil Ingestion Rate (kg dry soil/kg body weight-d) (*SIR*)	Home Range (acres)
Shrew	0.5	0.45	0.0045	0.1
Robin	0.52	0.207	0.0215	0.6
Vole	1.0	0.315	0.0079	0.08

Site-specific soil to prey (earthworms and plants) bioaccumulation factors (BAFs) will be derived for the former Rayonier Mill Site. Prey and co-located soil samples will be collected from selected areas on the former Rayonier Mill Site and analyzed for COPCs. Samples will be located in areas spanning the range of COPC concentrations expected to be encountered at the former Rayonier Mill Site.

Results of this analysis will be used to derive site-specific, soil-to-earthworm and soil-to-plant accumulation factors using the following formula:

$$BAF_{ij} = CP_{ij}/CS_j$$

Where:

BAF_{ij} = Bioaccumulation factor for the i^{th} prey type and j^{th} chemical
CP_{ij} = Concentration of j^{th} chemical in the i^{th} prey type (mg/kg dry weight)
CS_j = Concentration of j^{th} chemical in soil (mg/kg dry weight)

The bioaccumulation factor will be calculated for each prey type and chemical combination to be used in the wildlife exposure models using methods consistent with MTCA. Additional information on BAFs is provided in Section 5.4 of Volume II.

In accordance with MTCA, the derived soil screening levels will be compared to the upper one sided ninety-five percent confidence limit (95 percent UCL) on the true mean soil concentration. The former Rayonier Mill Site will be divided into sub-areas for ecological evaluation, based on the nature of available habitats (e.g., isolated areas and riparian-versus-upland habitat types). This determination will be made during implementation of the ecological RA. In addition to comparing concentrations of chemicals in site soils to the soil screening level, concentrations will also be compared to natural and/or area background concentrations. Background comparisons are required to distinguish site-related concentrations from non-site related concentrations of chemicals. This is particularly relevant for inorganic chemicals that occur naturally in the environment

A qualitative uncertainty analysis will be performed for the terrestrial ecological evaluation. Virtually every step of the evaluation process involves judgments that contribute to total uncertainty in the final evaluation of risk. The uncertainty analysis will summarize the uncertainties identified during all phases of the assessment, evaluate the impacts of those uncertainties on the risk assessment, and identify (to the extent possible) actions that could reduce uncertainty.

5.4.2.2 Ennis Creek Sediments

Sediment sample analytical data from Ennis Creek will be compared to applicable published sediment quality vales that are protective of aquatic organisms. The sediment data from the lower reach of Ennis Creek will also be compared to data collected from upstream areas to help distinguish mill site inputs from inputs attributable to the surrounding environs.

5.5 REMEDIAL INVESTIGATION REPORT

An RI report will be prepared that presents the results of all investigations conducted during the RI. All data will be reported in tabular form, and various map overlays and other plots will be used to present the information. The pertinent features of the RI report will be description of the investigations conducted, summary of the extent of contamination identified, characterization of potential migration pathways, and an RI. The RI report will follow the Ecology guidance.

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