Chapter 5
Risk Modeling

What's Covered in Chapter 5:

- Risk Modeling Approach
- Identifying Land Use Characteristics
- Risk Modeling Inputs
- Risk Modeling Output

The risk modeling component of the RAIMI estimates potential human health exposures at the neighborhood level through the use of exposure scenarios that can be refined specific to the amount and quality of data available. In the RAIMI Pilot Study, a simple scenario is applied to the concentrations that are predicted based on the dispersion of emissions from sources modeled, as described in Chapter 4. These estimated exposures are then converted to risk estimates through the use of standard risk models and application of standard hazard analysis techniques. This risk modeling component is necessary to provide the detailed contaminant-specific, source-specific, and location-specific information in a manner conducive to the identification and prioritization of risk management opportunities.

The general approach to risk modeling is to apply existing and current risk procedures, equations, and parameters to the RAIMI Pilot Study's estimated concentrations from multiple facilities, sources, and contaminants, compared with neighborhood receptors. As is often the challenge encountered in permitting a single facility with several combustion sources, determining the potential exposure resulting from literally hundreds of emission sources located throughout the assessment area requires a platform capable of accessing and utilizing vast amounts of data. Additionally, significant flexibility is required to tailor the risk modeling to site-specific conditions and identify concerns, as specified by RAIMI Pilot Study objectives.

Risk modeling for the RAIMI Pilot Study is conducted following guidance in the *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP), which implements the guidance in *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to*

Combustor Emissions for evaluating risk from emission sources, with specific equations and inputs as recommended in the *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* (RAGS), *Exposure Factors Handbook*, and *Integrated Risk Information System* (IRIS) (U.S. EPA 1989; 1991; 1997a; 1998a; 1998b; 1998c; 2000e).

This chapter describes the risk modeling component of the RAIMI Pilot Study. The overall approach to risk modeling is presented in Section 5.1. The implementation of risk modeling activities based on the overall approach is described in subsequent sections, including the identification of land use characteristics in the assessment area (see Section 5.2), importing ISCST3 air dispersion modeling results and establishing exposure locations for the air inhalation pathway (see Section 5.3), determining risk modeling inputs (see Section 5.4), and reviewing risk modeling outputs (see Section 5.5).

5.1 RISK MODELING APPROACH

The RAIMI Pilot Study design goals, presented in Section 1.2, identify several broad objectives with regard to the development, management, and usability of the risk and hazard estimates generated in the risk modeling component. Key elements of project design require the RAIMI Pilot Study methodology to (1) be a useful tool for permitting support to federal, state, community, and facility stakeholders, (2) provide a standardized and consistent means for the risk- and hazard-based assessment and prioritization from multiple emissions sources of multiple contaminants from multiple facilities, (3) provide the necessary levels of detail for risk-based source-specific decision making, (4) support the calculation and tracking of risks from hundreds of sources, and (5) be able to implement these goals through a versatile and dynamic project platform.

Of the three technical components of the RAIMI Pilot Study (emissions characterization, air dispersion modeling, and risk modeling), it is through the risk modeling component that the available tools, guidance, and databases come together to achieve the project design goals. These goals have been made achievable by recent developments in the implementation of State and Federal databases to routinely compile emissions data (as described in Chapter 3), by the maturation of guidance for evaluating risk resulting from air emissions sources, and technology advances in software and database tools that manage, model, and enable the timely and focused use of the emissions data and risk evaluations.

The HHRAP is national guidance developed to consolidate information presented in other risk assessment guidance and methodology documents previously prepared by EPA and State regulatory agencies. The purpose of the HHRAP is to summarize the procedures, equations, and inputs required to perform risk evaluations, and to addresses issues that have been identified while conducting such assessments at actual facilities. Thus, the HHRAP does not represent a new approach to risk assessment methodology, but rather a thorough evaluation of existing guidance and a compilation of recommended methodologies.

The HHRAP was developed for combustion facilities, and incorporates the necessary guidance protocols and recommendations for emissions source characterization, air dispersion and deposition modeling, and media estimating equations for evaluation of multi-pathway exposure. The guidance was developed for the particular case of one facility, which may have more than one combustion emission source and ancillary fugitive emission sources. However, specific application of the HHRAP, in conjunction with other national guidance and studies, to the broad case of the RAIMI Pilot Study (i.e., multiple facilities, emission sources, contaminants, and receptors) has proved successful in achieving RAIMI Pilot Study objectives and design goals.

Implementation of the risk modeling component for the Port Neches Pilot Study was conducted in various software applications including ACCESS^{TM} database software developed by Microsoft Corporation (Microsoft Corporation 1997) for doing the bulk of the computations, and IRAP-*h* View^{TM} risk modeling software (Lakes Environmental Software, Inc. 1998) for tabulating results. Enhanced capacity and functionality is also being evaluated through a more complete use of the GIS platform utilizing ArcView^{TM} software developed by Environmental Systems Research Institute, Inc. (Environmental Systems Research Institute, Inc. 1997).

Important consideration in the selection or development of the risk modeling component as related to meeting RAIMI project objectives include:

1. Direct import of the air parameters within the output files from ISCST3 (see Section 4.4);
2. Implementation of the exposure setting (scenario) and risk characterization components;
3. Capability to simultaneously calculate and track risks from multiple emission sources and contaminants based on emissions data obtained from the emissions characterization component;
4. Allowing for the direct modification or refinement of emission rate data to support the re-evaluation of risk on practically a real-time basis (in combination with the single-pass air dispersion modeling strategy outlined in Chapter 4); and
5. Existing within or can be directly linked to a GIS platform to provide expanded presentation and graphical evaluation of risk results and interim analyses.

Risk results and interim analyses (e.g., air modeling output, corrections to source locations, determining accuracy of land use mapped data, etc.) can be significantly enhanced if modeling components exist within or are directly linked to a GIS platform. At a minimum, it can comprehensive graphic presentation of results over aerial photography or other site specific mapping. Graphics presentation also provides the capability to graphically overview data sets from the U.S. Census Bureau's TIGER database. This can be especially beneficial for evaluating the representativeness of exposure inputs used in the risk modeling with respect to neighborhood characteristics and demographic attributes.

The general approach to risk modeling for the RAIMI Pilot Study is summarized in the following steps:

1. Create a project for the assessment area, and import a GIS base map of the assessment area to support identification of land use characteristics;

2. Import ISCST3 output of the modeled unitized air parameter values specific to each receptor grid node location contained within the defined receptor grid node array (see Section 4.3.3 for further discussion on use of unitized emission rates in air modeling) for each source modeled;

3. Conduct analyses (e.g., searches and plotting of air parameter values across land use areas of interest) on the imported air parameters values to identify the receptor grid node locations, specific to neighborhoods within the assessment area, where exposure will be estimated (see Section 5.1);

4. Enter into the risk modeling component the required contaminant specific (or other emissions profile to be evaluated as required by project objectives) emission rates for each source (see Chapter 3) and exposure parameter inputs for the respective pathway (see Section 5.3);

5. Execute the risk modeling component to calculate potential risk and hazard values (see Section 5.4) specific to emission sources, contaminants, and receptor locations selected for evaluation; and

6. Verify inputs and conduct computation checks.

The specific procedures and parameter inputs used in these steps are described in the following sections.

5.2 IDENTIFYING LAND USE CHARACTERISTICS

Land use characteristics of the assessment area are the primary factors used to determine which exposure pathways are applicable to a specific area or location being considered for evaluation, and which values might be used for some of the exposure scenario parameters used in the risk modeling. The initial phase of the RAIMI Pilot Study focuses on the air inhalation pathway across potentially impacted neighborhoods; typically defined by residential land use. To identify areas of residential land use within the assessment area, several sources of current land use information are obtained and reviewed, including the following:

> ***Land Use Land Cover (LULC) Maps* -** LULC data files describe the vegetation, water, natural surface, and cultural features on the land surface. The USGS provides these data sets and associated maps as a part of its National Mapping Program. The LULC mapping program is designed so that standard topographic maps of a scale of 1:250,000 can be used for compilation and organization of the land use and land cover data. LULC maps are available in digital formats.
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> ***Topographic Maps* -** Topographic maps are readily available in both hard copy and electronic format directly from USGS or numerous other vendors. These maps are commonly at a scale of 1:24,000, and in a tagged information file format (TIFF) with TIFF World File included for georeferencing.
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> ***Aerial Photographs* -** Hard copy aerial photographs can be purchased directly from USGS in a variety of scales and coverages. Electronic format aerial photographs or Digital Ortho Quarter Quads (DOQQs) can also be purchased directly from USGS, or from an increasing number of commercial sources. Orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. They serve a variety of purposes, from interim maps to field references for Earth science investigations and analyses. The digital orthophoto is useful as a layer of a geographic information system. Unlike a standard aerial photograph, relief displacement in orthophotos has been removed so that ground features are displayed in their true ground position. This allows for the direct measurement of distance, areas, angles, and positions. Also, an orthophoto displays features that may be omitted or generalized on maps.

In combination, these data sources provide substantial land use information and characterization. Applicable digital geographic data sources for the RAIMI Pilot Study assessment area are loaded into the risk modeling component as base maps to establish land use in the assessment area. LULC data is used to define land use area polygons, which were superimposed on topographic and aerial photograph coverage to verify the assigned land use determinations and confirm accurate spatial positioning. Exact boundaries of polygon land use area coverages being considered for evaluation, for example residential land use area representing a neighborhood, are verified using available topographic maps and aerial photographic coverages. Properly geo-referenced DOQQs covering the assessment area, overlays of the LULC map coverage, and the ISCST3 modeled receptor grid node array, provide excellent references for identifying land use areas and justifying selection of exposure locations.

5.3 IDENTIFYING EXPOSURE LOCATIONS

For each source and contaminant modeled, output from the execution the single-pass air modeling approach allows for the generation of risk and hazard values at one or all of the air modeling receptor grid nodes of interest within the assessment area. However, focus for the RAIMI Pilot Study, as stated in the objectives and presented in Chapter 6, is placed on the identification of residential land use areas or neighborhoods within the Port Neches Assessment Area subject to the highest potential impact from any combination of sources and/or contaminants. As discussed in Chapter 6, estimated risk and hazard values at additional random locations, other than highly impacted neighborhood areas, have also been presented in this report to illustrate how significantly source attribution and impacts can vary with location. It is important to note, that although this approach and presentation focuses on selection of locations of concern to view results in comparison of a certain risk-based floor, the RAIMI method allows for determination and viewing of results for all locations and contaminants for the entire assessment area, providing an “estimated risk surface” for the whole area, whether or not it rises at any given point to levels anyone would consider of interest (although all grid node locations were analyzed for the Port Neches Pilot, presentation of results in this report has been restricted to a few of these locations to illustrate particular capabilities and the accomplishment of project objectives).

To identify exposure locations within a residential land use or neighborhood, all air parameter values within ISCST3 output plot files for each modeled source are loaded directly into the risk modeling component, and the boundaries of the residential land use areas or neighborhoods are graphically identified on background mapping within the GIS platform. Since in this case study the objective is to identify the areas of highest possible risk within residential land use areas of concern (neighborhoods), exposure locations within the neighborhoods were identified by searching through the available ISCST3 modeled air parameter values, specific to all emission sources evaluated, to determine those receptor grid node locations that exhibit the following:

- Highest modeled annual average unitized vapor phase air concentration;
- Highest modeled annual average unitized particle phase concentration; and
- Highest modeled annual average unitized particle-bound phase concentration.

Although modeled, wet and dry deposition concentrations are not considered in the evaluation of the air inhalation pathway. However, consistent with the single-pass air modeling approach described at the beginning of Chapter 4, the focus of is the up-front production of all necessary air modeling data to support current and potential future risk modeling needs. In addition, procedures different from that identified above may be employed for identifying areas to evaluate risk if specific project objectives differ (e.g., area averaging or population based analyses).

This analysis is performed for emissions from each individual emission source as well as for the combined emissions from all sources, often resulting in multiple exposure locations being identified for evaluation within each neighborhood. Results of the receptor identification analysis was performed with both the risk modeling software and ArcView^{TM}, to provide adequate cross-check of accuracy.

5.4 RISK MODELING INPUTS

Specific inputs to risk modeling, as well as the tracking of inputs, are required to support the designed output which is segregated specific to each emission source, exposure location, exposure pathway, and contaminant (see Section 5.5), and generally include the following:

- Speciated emission rates specific to each emission source evaluated;
- Fate and transport parameter values specific to each exposure location evaluated;
- Exposure parameter values specific to each exposure pathway evaluated; and
- Contaminant properties specific to each contaminant evaluated.

As previously noted, risk modeling procedures and required inputs for the RAIMI Pilot Study are summarized in the HHRAP, which is consistent with the methodology provided in *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions* for evaluating risk from emission sources, with specific equations and inputs as recommended in RAGS, *Exposure Factors Handbook*, and IRIS (U.S. EPA 1989; 1991; 1997a; 1998a; 1998b; 1998c; 2000e). While some input parameter values are emission source and site specific, and have to be hand entered when building a project, all other input values are already available for review, revision (if necessary), and execution.

5.4.1 Contaminant-Specific Emission Rates

Speciated or contaminant-specific emissions rates, obtained during the emissions characterization component (see Chapter 3) for each emission source, are inputs to the risk modeling and allocated to the unitized air parameter values obtained as output from air modeling. Speciated emission rates are entered on a gram per second basis; with naming verified using CAS numbers. Speciated or contaminant-specific emission rates are required since toxicity values utilized in risk modeling are also contaminant specific. Contaminant specific results are also the most useful information for supporting consideration of risk management options. Emission rate values input for sources evaluated in the risk modeling, and corresponding to the results presented in Chapter 6, are provided in the project files in Appendix IRAP.

As noted in Chapter 4, the capability to allocate speciated emissions to unitized air parameter values provides significant flexibility to the RAIMI Pilot Study for the re-evaluation of multiple emissions scenarios (e.g., permit conditions, revised emissions inventories, possible benefit of installing various types of pollution control equipment) to determine effect on resultant risk and hazard projections. For example, the risk to neighborhood receptors due to a 25 to 50 percent range of decrease in contaminant-specific emissions from a particular source can be evaluated by allocating the new emission rate to the unitized air parameters; it is not necessary to repeat the air dispersion modeling for the source unless significant changes occur to physical source parameter values (e.g., source location, physical dimensions, exit velocity.

5.4.2 Fate and Transport Parameters

For the Port Neches Pilot Study, fate and transport parameter input values required in risk modeling to calculate exposure media concentrations are provided by the HHRAP and specific to each exposure location evaluated. Fate and transport parameter values are reviewed to determine representativeness to exposure location characteristics, and revised accordingly. However, since the initial phase of the RAIMI Pilot Study focuses only on the air inhalation pathway, which utilizes an exposure media concentration based solely on air parameter values from air modeling and entered emission rates, revisions to fate and transport parameter values are typically not applicable. Fate and transport parameter values input for each exposure source location evaluated in the risk modeling component, and corresponding to the results presented in Chapter 6, are indicated in Appendix IRAP. It is important to note that the RAIMI project platform is flexible with regard to equations and toxicity benchmarks applied withing the risk modeling component. Therefore, focus in this report has been to illustrate capability and function as opposed to calculation construct used for this particular pilot study.

5.4.3 Exposure Scenario

In order for modeled concentrations to be used for exposure estimation, a series of assumptions must be made as to how, when, and where the exposure (i.e., contact with persons within the study area) takes place. This set of assumptions is usually called the exposure scenario. The initial phase of the RAIMI Pilot Study focuses on the air inhalation pathway for residential land use areas or neighborhoods subject to the highest potential impact. Therefore, the exposure parameter values selected for the exposure scenario, which will be used to calculate estimates of risk, are consistent with those parameter values for the adult resident and child resident air inhalation exposure pathways, as described in the HHRAP (U.S. EPA 1998b). A listing of the exposure parameters, and respective numeric values used for the initial phase of the RAIMI Pilot Study, are provided in Table 5-1.

For the air inhalation pathway, the factors that affect exposure include air contaminant (vapor and particulate) concentrations at each exposure location, respiration rate during the period of exposure, length of exposure, and time period over which the release of emissions occurs. As discussed in Section 4.4, air parameter values output for the vapor, particulate, and particle-bound air phases, are utilized specific to each exposure location to calculate exposure media (i.e., air) contaminant concentrations. Respiration rates of 0.63 cubic meters per hour (m^3/hr) for the adult and 0.30 m^3/hr for the child are used to represent normal or non-working average inhalation rates (U.S. EPA 1998b). These values are consistent with the *Exposure Factors Handbook* (U.S. EPA 1997a), and about 25 percent less than inhalation rates specified in RAGS (U.S. EPA 1989; 1991; 1998a).

Values used for length of exposure are consistent with values, and associated assumptions and basis, reported in the HHRAP (U.S. EPA 1998b). A value of 30 years is used to represent the time period over which the release of emissions from a source occurs. Specific values for this parameter are not available for emission sources evaluated, and therefore, the value of 30 years is an assumed value based on the intended life expectancy of industrial facilities and other emission sources considered. In addition, 30 years is also commonly considered to be the upper percentile amount of time that people live in the same house. Values for this and other exposure inputs are always an important consideration for site-specific analysis and the values adopted should be reflective of project objectives, parameter

TABLE 5-1

EXPOSURE PARAMETER VALUES

Parameter Description	Units	Resident Adult	Resident Child
Averaging time for carcinogens	yr	70	70
Averaging time for noncarcinogens	yr	30	6

Parameter Description	Units	Resident Adult	Resident Child
Body weight	kg	70 (154 pounds)	15 (33 pounds)
Exposure duration	yr	30	6
Exposure frequency	day/yr	350	350
Inhalation exposure duration	yr	30	6
Inhalation exposure frequency	day/yr	350	350
Inhalation exposure time	hr/day	24	24
Inhalation rate	m^3/hr	0.63	0.30
Time period over which release of emissions occurs	yr	30	30

Notes:

day/yr	Day per year
hr/day	Hour per day
kg	Kilogram
m^3/hr	Cubic meter per hour
yr	Year

sensitivity, and intended use of the results. For the Port Neches Pilot Study, the numerical value of exposure inputs is not the focus, but rather determining that the flexibility exits to make revisions to values as warranted. It should also be noted that reducing the value of this particular parameter, time period over which release of emissions is assumed to occur, by half will typically not result in a significant (i.e., by an order of magnitude) reduction in the numeric results of the risk modeling. Exposure parameter values input in the RAIMI Pilot Study for the risk modeling component, and corresponding to the results presented in Chapter 6, are provided in Appendix IRAP.

Although design of the RAIMI Pilot Study provides the ability to change exposure parameter values between exposure scenarios, and even from location to location, for the RAIMI Pilot Study, a simple scenario was used which assumes that residents in the area breathe the average concentrations from the models for 24 hours per day, 350 days per year. Exposure via inhalation of contaminants is influenced by a receptor's daily activities (e.g., resting, playing, working) and location (i.e., indoors, outdoors, driving, occupation) (U.S. EPA 1987). The numerical influence of these daily exposure elements are also expected to be receptor and exposure location specific. For example, a receptor may spend more time indoors, which may tend to decrease exposure to some contaminants (but actually increase exposures to others), but work at a location that has significantly higher exposure concentrations compared to the residence exposure location evaluated. Considering the objectives of the RAIMI Pilot Study, the extensive effort required to explicitly model each of these daily exposure elements is not supported. Instead of providing exposure profiles as inputs, risk modeling for the RAIMI Pilot Study is based on the first-order assumption that exposure parameters and values utilized are representative of long term average exposure. Since daily activities and locations may be important, design of the RAIMI Pilot Study allows for additional risk modeling runs to be conducted on a case-by-case basis (e.g., incorporate exposure profiles for the general population, vary exposure input values specific to geographic location or demographics), but with resource expenditures to refine exposure parameters correlated to required refinement of results. The focused integration of refinement during the risk modeling is intended as an approach for balancing RAIMI Pilot Study objectives with resource expenditures.

5.4.4 Contaminant Properties

Contaminant properties, specific to each contaminant evaluated, are required input to the risk modeling to calculate exposure media concentrations and to evaluate risk as a result of toxicity. For the purposes of the RAIMI Pilot Study, values reported in the HHRAP have been utilized specific to each contaminant evaluated. Since the reporting of new or revised toxicity values is expected to occur on a somewhat frequent basis, contaminant specific toxicity values utilized in the risk modeling are compared to values reported in current versions of IRIS and Health Effects Summary Tables (HEAST) to maintain these values as current. It is assumed that the reference doses and cancer potency factors in IRIS and HEAST are appropriate for purposes of generating numeric cancer risk and hazard estimates for the contaminants modeled. As documented in the respective databases noted, reference doses and slope factors have undergone review and approval by either EPA headquarters work groups and/or regional EPA toxicologists. The specific values used in the RAIMI Pilot Study are provided in the project files in Appendix IRAP.

5.5 RISK MODELING OUTPUTS

For each source and contaminant modeled, output from the execution of the risk component provides risk and hazard based on estimates of potential impacts posed to neighborhoods (or any air modeling receptor grid node of interest) from contaminant emissions within the assessment area. Output is segregated specific to each emission source, exposure location, exposure pathway, and contaminant. The RAIMI Pilot Study calculated individual risk and hazard information for the exposure locations based on a simple exposure scenario. Population risk and hazard are not calculated, however, design of the RAIMI Pilot Study allows for additional risk modeling runs to be conducted on a case-by-case basis to address such analyses, provided data refinements would be required for exposure estimates and population demographics. Carcinogenic risk information is communicated as a probability that an individual receptor will develop cancer based on the unique set of exposure and toxicity assumptions established in Section 5.4. Potential non-cancer effects, or hazard estimates, are quantified as a measure of the magnitude of an individual receptor’s potential exposure relative to a standard exposure level thought to represent a level at which no harm will occur even over a lifetime of exposure. The estimation of potential risk and hazard are described in the following sections.

5.5.1 Carcinogenic Risk

For carcinogenic contaminants, risk values represent the incremental probability that an individual will develop cancer over a lifetime as a result of a specific exposure to a carcinogenic chemical (U.S. EPA 1989). Contaminant-specific cancer risk is calculated using an exponential formula, but at risks less than about 10^{-2}, it is approximated linearly by multiplying the inhalation cancer slope factor (CSF) by the average daily intake over the exposure period via inhalation (U.S. EPA 2000e). The lifetime average daily intake via inhalation is a function of the contaminant concentration in air and the exposure parameters established in Section 5.4. The equations used to calculate the lifetime average daily dose are described in detail in the HHRAP, Appendix C, Table C-2-1 (U.S. EPA 1998b).

Results of the risk calculations are presented in the risk summary tables in Appendix IRAP.

5.5.2 Noncarcinogenic Hazard

The RAIMI Pilot Study uses the standard risk assessment method for calculating a hazard quotient (HQ) for noncarcinogenic effects. This approach is based on the assumption that such effects exhibit a threshold below which no adverse effects will be observed and above which some adverse effect may be observed. The noncarcinogenic HQ for each contaminant at an exposure location is calculated as a ratio of the contaminant specific estimated (modeled) air concentration to the contaminant specific inhalation reference dose (R*f*D). R*f*D values used in the RAIMI Pilot Study are derived from the inhalation reference concentration (R*f*C) utilizing the methodology outlined in HEAST (U.S. EPA 1997c; 1998b). Both the R*f*D and R*f*C values are the thresholds that represents the estimated daily concentration of a chemical in air, the exposure to which over a specific exposure duration poses no appreciable risk of adverse health effects, even to sensitive populations (U.S. EPA 1989; 2000).

Results of the hazard calculations are presented in the risk summary tables in Appendix IRAP.