

**ENHANCED ENVIRONMENTAL SITE ASSESSMENT  
SOFTWARE SYSTEM**

By

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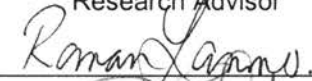
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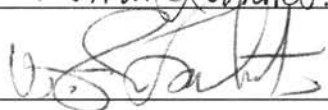
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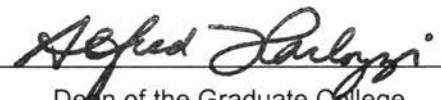
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## NOMENCLATURE

AOC	Area of Contamination
APIDSS	American Petroleum Institute Decision Support System
ASCE	American Society of Civil Engineers
ASGWE	Association of Ground Water Scientists and Engineers
AST	Above-ground Storage Tank
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BRAC	Base Realignment and Closure Program
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (Superfund)
CERCLIS	CERCLA Information System
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulation
CWA	Clean Water Act
DEP	Data Entry Program
DGPS	Digital Global Positioning System
DLL	Dynamically Linked Library
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSaRP	Data Storage and Retrieval Program
E-FAST	Environmental Field Assessment and Survey Technology
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act

ERNS	Emergency Response Notification System List
ESA	Environmental Site Assessment
ESA	Endangered Species Act
EESASS	Enhanced Environmental Site Assessment Software System
FR	Federal Register
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical-User Interface
HA	Hazard Assessment
HEAST	Health Effects Assessment Summary Tables
HH&E	Human Health & the Environment
HHWE	Human Health, Welfare, and the Environment
HM	Hazardous Material
HMTA	Hazardous Materials Transportation Act
HRS	Hazard Ranking System
HSWA	Hazardous and Solid Waste Amendments
HTML	Hypertext Markup Language
HW	Hazardous Waste
IRIS	Integrated Risk Information System
ISO	International Organization for Standardization
MSDS	Material Safety Data Sheet
MEI	Maximum Exposed Individual
NAS	National Academy of Science
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Regulatory Commission
O/O	Owner /Operator

OSHA	Occupational Safety and Health Act
OTA	Office of Technology Assessment
PA	Preliminary Assessment
PCB	Polychlorinated Biphenyl
PET	Precipitation and Evapotranspiration
POC	Point of Compliance
POD	Point of Departure
POE	Point of Exposure
POTW	Publicly Owned Treatment Works
PR	Preliminary Review
PRAP	Preliminary Risk Assessment Program
PRP	Potentially Responsible Party
RA	Remedial Action
RaDP	Reporting and Documentation Program
RBCA	Risk Based Corrective Action
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RfC	Reference Concentration
RfD	Reference Dose
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RISC	Risk-Integrated Software for Cleanups
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SEC	Securities and Exchange Commission
SI	Surface Impoundment
SI	Site Inspection
SOP	Standard Operating Procedure

STTR	Small Business Technology Transfer Research
SW	Surface Water
SWDA	Solid Waste Disposal Act
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage, or Disposal
UIC	Underground Injection Control
USC	United States Code
USCA	United States Code Annotated
UST	Underground Storage Tank
USGS	United States Geological Survey
VaDSP	Visualization and Decision Support System
VOC	Volatile Organic Compound
WP	Waste Pile

# CHAPTER 1

## INTRODUCTION TO EESASS

### 1.1. Introduction

The Enhanced Environmental Site Assessment Software System (EESASS) is a collection of computer software routines (Microsoft Visual Basic<sup>®</sup>, Microsoft Access<sup>®</sup>, Hypertext Markup Language<sup>®</sup>, ArcView<sup>®</sup>, and DynaMo<sup>®</sup>) that together can assist an assessor in performing an environmental site assessment (ESA) and in assessing and subsequently managing environmental hazards at chemically contaminated site. EESASS is a component of the Environmental Field Assessment and Survey Technology (E-FAST) that was developed by Nomadics, Inc. and Oklahoma State University under a U.S. Air Force Small Business Technology Transfer Research (STTR) program grant. E-FAST components include:

- ◆ Computing platform and operating system
- ◆ Expander unit and PCMCIA cards
- ◆ Environmental sensors and software
- ◆ Video capture unit and software
- ◆ Audio capture unit and software
- ◆ Bar code scanner and software
- ◆ Global positioning system unit and software
- ◆ EESASS

Nomadics Inc. was responsible for the hardware (Computer Platform and operating system, Expander Unit and PCMCIA cards, environmental sensors, bar code scanner and software, and GPS unit) in E-FAST whereas OSU was responsible for ESA software (video and audio capture, GIS, and EESASS).

## 1.2. What Is ESA?

Environmental site assessments (ESAs) are performed for commercial real estate transactions to evaluate the condition of properties. In E 1527-93 and E 1528-93, ASTM (American Society For Testing and Materials) defines ESA as the process by which a person or entity seeks to determine whether a particular parcel of real property (including improvements) is subject to recognized environmental conditions. A recognized environmental condition is indicated when the presence or likely presence of hazardous substances is found under conditions that demonstrate that an existing release, past release, or potential release of hazardous substances into structures or the environment. The purpose of conducting an environmental site assessment is to facilitate decision-making about what further investigation, if any, should be conducted to estimate the risk that may be posed by such releases. The quantification of risk is a prerequisite to decision-making about how the risk should subsequently be managed. Thus, an ESA should be regarded as a risk management tool. An ESA can provide a measure of control and protection for owners, buyers, lenders, and persons unintentionally involved with properties. This control can benefit liability management, risk avoidance, business and public relations, and regulatory compliance.

## 1.3. Definitions of Terms

To provide clarification, the following definitions are provided.

ESA TERM	DEFINITION
Absorption Factor	The fraction of delivered dose that is absorbed into tissues
Acceptable Risk Range	The range of risk lying between <i>de minimis</i> and <i>de manifestis</i> that may be judged as acceptable depending on the tradeoffs required to reduce it further (e.g., cost, short term effectiveness, implementability, and political acceptability)
Action Level	The environmental concentration of a toxicant that is equivalent to <i>de minimis</i> risk as a point of departure; units are usually mg/l water, mg/kg soil, and $\mu\text{g}/\text{m}^3$ air
Administrative Order	See "compliance order"
Aquifer	An underground zone of saturation through which groundwater moves from a region of higher pressure to a region of lower pressure
Area of Contamination	Portion of the environment contaminated by a release of toxicants, such as a surface spill area or a leachate-contaminated soil horizon, from which toxicants migrate through the environment to a receptor

ESA TERM	DEFINITION
ASTM	American Society for Testing and Materials; the organization that issued the standard of professional practice for the conduct of environmental site assessments
Averaging Time	The period of time that an MEI receptor is assumed to be exposed and which forms the basis for the calculation of toxicity values; set to 70 years (lifetime) for carcinogens and residential exposures to systemic toxicants and 30 years for occupational exposures to toxicants
Baseline Risk	The level of risk that exists before any risk mitigation is conducted
Carcinogenic	Toxicants that produce cancer effects (e.g., tumors, neoplasias)
Chronic	Adverse effects are experienced after seven years of exposure
Decision Support	A technique used to aid decision making by simplifying the processing and/or presentation of information; used in EESASS to simplify Phase III evaluation of potential risk mitigation strategies
<i>De Manifestis</i> Risk	Risk above which risk reduction is mandatory; roughly equivalent to 10 <sup>-4</sup> cancer risk
<i>De Minimis</i> Risk	Risk that is below a level of concern and therefore can be ignored; roughly equivalent to 10 <sup>-6</sup> cancer risk or HI=1.0 systemic risk
Dose	The concentration of a toxicant in a receptor's body, usually expressed as mg of toxicant / kg of body weight / day of exposure
Environmental Concentration	The concentration of a toxicant in the environment, usually expressed as mg/l of water, mg/kg of soil, and µg/m <sup>3</sup> of air
Environmental Medium	Same as "migration pathway"
Exposure Duration (ED)	The average time per day that a receptor is exposed to a toxicant (hrs/24 hours)
Exposure Frequency (EF)	The average number of days per year that a receptor is exposed to a toxicant (days/365 days)
Exposure Pathway	Same as "migration pathway"
Exposure Period (EP)	The number of years within the averaging time that a receptor is exposed to a toxicant (years)
Exposure Time (Et)	The average time that a receptor is exposed to a toxicant over the course of the averaging time (years) = ED*EF*EP
GIS	Geographic Information System; used to display spatial images and underlying informational attributes
GPS	Global Positioning System; a satellite system used to relay spatial data to earth receivers so that precise locations can be determined
GUI	Graphical User Interface; the graphical displays that the computer user sees which facilitates communication between the user and the computer application
Hazard	The linkage between an environmental release of a toxicant and the adverse effect that it produces in a receptor exposed to it

ESA TERM	DEFINITION
Hazard Identification	The qualitative assessment of threat; that is, the confirmation of a causal chain from (1) a source from which there has been (2) a release of toxicants to the environment that (3) forms an area of contamination from which (4) the toxicants can migrate through the environment to (5) an exposed receptor who (6) intakes the toxicants into its body via one or more routes of entry, which (7) subsequently results in a dose high enough to (8) produce an adverse health effect that (9) threatens the receptor's health
Hazard Index	The sum of hazard quotients across similar toxicological endpoints and parameters
Hazard Quotient	The ratio of receptor dose to the reference dose; a ratio exceeding "1" indicates unacceptable risk
Imminent and Substantial Endangerment	Same as <i>de manifestis</i> risk
Intake	The entry of a toxicant into the body of the receptor
Intake Assumption	The EPA-specified default value for the volume or weight of environmental medium taken into the body of a receptor during a 24 hour cycle (e.g., 20 m <sup>3</sup> air, 2 l water, 100 mg soil)
Intake Route	One of three routes by which toxicants can enter the body of a receptor: oral ingestion, pulmonary inhalation, and dermal absorption
Material Management Unit	A device or structure used to store, transport, or process raw materials, intermediates, byproducts, or final products that have economic value and which are managed to conserve this value
Most Exposed Individual (MEI)	A receptor who is expected to accumulate the maximum dose from exposure to a particular hazard during the averaging time
Migration Pathway	One of five means by which toxicants can move through the environment to a receptor: air, surface water, ground water, surface soil, subsurface soil, and food (subdivisions of these pathways are also possible, for example indoor versus outdoor air or particulate versus gas dispersion); pathways can also occur in combination (e.g., from surface soil to groundwater or from groundwater to subsurface soil to air)
Point of Departure	The initial level of risk that is assumed to be "actionable", that is, require further investigation and potential mitigation (equivalent to <i>de minimis</i> risk)
Receptor	Living organism; in EESASS, only human receptors are considered.
Recognized Environmental Condition	A term used in Phase I ESAs to define the existence of a hazard
Release	Any intentional or unintentional emission, discharge, leak or escape of toxicants from a source into the environment
Remedial/Corrective (R/C) Action	Risk reduction measures taken to mitigate risks to acceptable levels



ESA TERM	DEFINITION
Residual Risk	The level of risk remaining after risk mitigation measures have been completed
RfC	Reference concentration (units depend on environmental medium) that is concentration-equivalent of the reference dose and thus represents a concentration of a systemic toxicant that will produce no adverse effect, even to sensitive receptors after a lifetime of exposure
RfD	Reference dose (mg/kg/day); represents the toxicant concentration in a receptor below which no adverse systemic (non-carcinogenic) effects are expected, even to sensitive receptors after a lifetime of exposure
Risk	The probability of an adverse effect, the severity of an adverse effect, or the product of these two (usually expressed as a dimensionless number)
Risk Assessment	The qualitative (hazard identification) and quantitative (risk characterization) assessment of threat to receptors caused by environmental exposure to toxicants
RBCA	Risk-Based Corrective Action; one of the ASTM standards for the conduct of environmental risk assessment and remediation
Risk Characterization	The quantitative estimation of risk magnitude; for carcinogenic risks, this number is usually expressed as a probability; for systemic risks, this number is expressed as a magnitude
Risk Management	The definition, evaluation, selection, and implementation of remediation (risk reduction) measures to mitigate risks to acceptable levels
Risk Reduction	The mitigation of risk to acceptable levels
RSD	Risk specific dose (mg/kg/day); represents the toxicant concentration in a receptor below which the probability of cancer is less than the specified risk level (e.g., $10^{-6}$ )
Slope Factor	A dimensionless number used to represent carcinogenic potency that is the ration of carcinogenic response to dose; abbreviated as SF, CSF (cancer slope factor), CPF (cancer potency factor), q, q <sub>1</sub> , or q*
Source	Any waste or material management unit that generates, transports, stores, treats, or disposes of toxicants
Subchronic	Adverse effects are experienced between two weeks and seven years after exposure
Substantial Threat	A level of risk lying between <i>de minimis</i> and <i>de manifestis</i>
Systemic	Toxicants that produce non-carcinogenic effects
Threat	Actual or potential damage to the health of a human or ecological receptor
Toxicant	A man-made poison (as opposed to a naturally-occurring poison, or toxin)
Toxicity Value	A dose that is believed to pose <i>de minimis</i> risk (e.g., point of departure RSDs for carcinogens and RfDs for systemics)

ESA TERM	DEFINITION
Toxicological Parameter	The specific adverse health effect that is the focus of risk assessment (liver toxicity, liver cancer, hemorrhaging, fetal malformation, etc.)
Toxicological Endpoint	The type of health effect that is the focus of risk assessment (e.g., mortality/lethality, morbidity/sickness)
Toxin	A natural poison
Tree View	The panel lying to the left of the GUI input forms that depicts the form folders that are available in EESASS
Unacceptable Risk	Risk that exceeds the <i>de minimis</i> risk threshold
Unsaturated Zone	The zone of aeration lying above a saturated zone; also known as "vadose" zone
Unit	Generic term referring to a material management unit or waste management unit
Waste Management Unit	A device or structure designed to transport, store, treat, and/or dispose waste

#### 1.4. Importance of Environmental Site Assessment

Environmental Site Assessment is a powerful management tool. It can be used to:

- (1) satisfy one of the requirements to qualify for the *innocent landowner defense* to CERCLA liability;
- (2) identify the presence or likely presence of any hazardous substances or petroleum products into structures on the property or into the ground, groundwater, or surface water of the property;
- (3) better understand liabilities of acquiring property with environmental problems;
- (4) avoid significant clean-up costs;
- (5) minimize liabilities;
- (6) avoid foreclosing and acquiring environmental problems;
- (7) establish a baseline for the protection of all property transactants (Buyer, Seller, Lender); and
- (8) assess risk.

#### 1.5. Parties Involved in an Environmental Site Assessment

The purpose of environmental site assessment depends on the client's association with the property. The client may be a (1) seller, (2) buyer, (3) lender, (4) lessor/lessee, (5) broker representing a buyer or seller, or (6) corporate shareholder. They all seek to determine the

probability that the property is or can become a liability due to hazardous substances on and/or associated with the property, and to reveal environmental factors that could restrict land use and development. Reasons for performing environmental site assessment vary with the perspective of the parties involved in any property transfer. The following describes the vested interests of the parties involved in property transactions.

- *Perspective of a Buyer:* A buyer desires to avoid acquiring contaminated property, which could result in an expensive cleanup, along with bewildering legal liability and land use. If a buyer still desires the property, even though it is known to be contaminated, it must define the extent and severity of contamination by the time of closing. The buyer may wish to use this information to negotiate a lower price, force disclaimers into the contract, or establish a shared responsibility for remedial action. The buyer may use an environmental site assessment to establish the property's condition at the time of changing ownership.
- *Perspective of a Seller:* A seller must characterize the environmental condition of a site at the time of transfer to help assure the seller that it will not be held liable for contamination that occurs after the sale. This activity is referred to as a baseline environmental assessment. The seller may also desire a baseline environmental assessment to verify that a property is uncontaminated in order to improve its marketability and enhance its value.
- *Perspective of a Lender:* Any party that serves as a lender for a property acquisition should require an environmental real estate audit. A lender's risk is created by holding a secured interest in the property (BNA 1989). Should a borrower default, the lender may be forced to foreclose and thereby assume ownership of the property. Without having performed a due diligence investigation, the lender becomes as liable for environmental contamination as any other owner is. The difference between an owner-operator and a lender, under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), is that the "owner" does not include "... a person who, without participation in the management of a vessel or facility, holds indicia of ownership primarily to protect his security" (Cahill 1996).

- *Lessor and Lessees:* Lessors are exposed to strict liability for environmental contamination resulting from activities of their lessees. If the lessee is financially unable to bear the costs for cleanup, the problem reverts to the lessor.
- *Brokers:* Brokers do not have liability under CERCLA or state Superfund laws if acting solely in the capacity of a broker. However, brokers have a professional duty to inspect and disclose. Under this premise, they may be held liable where environmental matters have not been handled properly during a real estate transaction. Real estate brokers must obtain extensive disclosures from the seller regarding the seller's knowledge of the condition of the property as to both environmental and other matters. The broker also has a duty to inform the parties to a transaction of the existence of environmental laws and concerns. He is obligated to inform the buyer of any potential problems found during an inspection.
- *Corporate Officers, Directors, Shareholders, and Successors:* Corporate structure has often been used by shareholders as a shield against environmental liability. Though shareholders risk loss of their stock investments, they have no personal liability if the assets of the corporation are insufficient to satisfy obligations. The corporate structure, however, does not provide protection against direct liability for one's own breach of civil or criminal law. Strict liability for cleanup of hazardous substance releases can be imposed on operators of contaminated property, including corporate officers, employees, and shareholders who exert managerial control over the property.

## **1.6. Applications of Environmental Site Assessment**

Environmental site assessments are becoming increasingly incorporated into environmental programs everywhere. Though its roots can be found in laws as old as 1970, the practice of environmental site assessment has grown explosively during the last ten years. This trend is expected to continue because of public sentiment concerning environmental hazards and growing Congressional interest in risk-based decision-making. Site assessments are now conducted under a number of federal programs, in other countries, and by the private sector.

In the federal arena, environmental site assessments are conducted under several programs. For example, they are incorporated as part of the CERCLA section 106 remedial response action

program, specifically the preliminary assessment/site investigation (PA/SI) and remedial investigation (RI) phases (EPA 1989a, 1989b, 1992). The Agency for Toxic Substances and Disease Registry (ATSDR) in the Public Health Service, U.S. Department of Housing and Human Services, is required by CERCLA to conduct toxicological profiles of CERCLA hazardous substances for use in site assessments under Superfund. Similarly, site assessments are included in the Resource Conservation and Recovery Act (RCRA) corrective action program under sections 3004(u), 3004(v), 3008(h), 3013, and 7003, particularly in the RCRA facility assessment (RFA) and RCRA facility investigation (RFI) stages (see proposed regulations at 40 CFR 264 Subpart S). RCRA section 3019 requires environmental site assessments under its exposure information and health assessment provisions. Under the National Environmental Policy Act (NEPA) section 102(2)(C), environmental impact studies are required which involve environmental site assessments (Henson 1993). EPA's brownfields initiative also relies on site assessments to return contaminated property to productive use more quickly. Federal agencies involved in land management, such as the Department of Defense (DOD), the Department of Energy (DOE), and the Department of the Interior (DOI), also conduct environmental site assessments. DOD performs site assessments as part of its Base Realignment and Closure (BRAC) program.

The international community is also rapidly moving toward the routine use of ESAs in business transactions through the International Organization for Standardization (ISO), based in Geneva, Switzerland. ISO's 14015 standard will address ESAs.

The expense of environmental cleanup has exerted extreme pressure on the private sector as well as public sectors. As discussed above, ESAs are conducted to identify environmental impairment liability as prerequisites for property, investment, and loan transactions.

### **1.7. Phases of the ESA Process**

Environmental site assessment is an investigatory procedure developed to assist the documentation of the environmental condition of a property, as it exists at that particular time. An environmental site assessment is typically conducted in four phases (Hess 1993).

Phase I generally involves non-intrusive research to determine the potential for significant onsite contamination and the regulatory, business, and exposure liability which may result from such a finding. The initial focus of an assessment is to determine if the potential for contamination exists or not. The environmental professional will initially investigate a property through its paper history and then progress to a site investigation. An assessment should also include a detailed examination of the property's prior owners and operators. Documented information concerning the business formerly on the site will aid in judging the types of potential contamination that should be investigated.

Typically, Phase II of an environmental site assessment characterizes areas of contamination. Sample collection is followed by certified laboratory analyses of soil and groundwater, products, wastes, and unidentified materials are usually required. Geophysical investigation, such as electrical resistivity and conductivity surveys that can be used to locate buried waste drums and to delineate high chloride concentrations in groundwater, also may be employed.

A Phase III environmental site assessment entails remediation of contamination. This may require relatively minor activity (e.g., excavation and landspreading of contaminated soil) or be extensive and complex (e.g., incineration of contaminated soil and *in situ* groundwater remediation). Costs of environmental cleanups vary widely and can easily reach many millions of dollars.

Case closure is conducted during Phase IV of an environmental site assessment. An extended period of sampling is typically necessary to prove that contaminant levels are acceptable before a case can be closed. Currently, post-closure care may be required for hazardous waste facility closure under RCRA and post-remediation care under CERCLA. Expenses for such care can be considerable due to the length of time required for competent closure control.

### **1.8. Research Objectives**

The goals of EESASS are to

- (1) develop a well-defined ESA protocol that will ensure compliance with applicable federal and state requirements for the conduct of environmental site assessments;

- (2) improve the quality and consistency of environmental site assessments;
- (3) improve the speed at which environmental site assessments are completed by automating the protocol;
- (4) add a preliminary risk assessment component to the environmental site assessment protocol so that subsequent risk assessments can be more efficiently and defensively focused; and
- (5) improve the utility of environmental site assessments by adding powerful decision support functions.

### **1.9. Contributions to This Research**

A number of graduate and undergraduate research assistants worked on this project during the last three years. In addition, several individuals from Nomadics, Inc. assisted the project team during EESASS development. Under the guidance and direction of Dr. Will Focht, my responsibilities in this project were to:

- participate in the design of the Phase I, Phase II, and Phase III EESASS protocols using ASTM, ASCE, ATSDR, AGWSE, and SOP standards and guidance documents as well as expert judgments;
- develop the Phase I, Phase II, and Phase III graphical user interface (GUI) forms using Microsoft Visual Basic 6.0<sup>®</sup>;
- assist in the design of the Phase 1, Phase II, and Phase III EESASS reports;
- develop and assist other research team members in the design of the EESASS relational database using Microsoft Access 97<sup>®</sup>;
- assist other team members in developing the Report Generator using MS Visual Basic<sup>®</sup> 6.0 and HTML<sup>®</sup>;
- assist in the design of the form controller using MS Access 97<sup>®</sup>; and
- serve as a coordinator in the management of the overall EESASS project.

## CHAPTER 2

### ESA STANDARDS AND CURRENT ESA METHODOLOGIES

#### 2.1. Introduction

The history of environmental site assessment began in 1977 as companies faced increasing environmental liability. ESAs were originally performed as a part of environmental auditing. Environmental auditing was initiated by Security and Exchange Commission (SEC) in enforcement actions against three large companies – Allied Chemical Corporation in 1977, United States Steel in 1979, and Occidental Petroleum in 1980 (Cahill and Kane 1994). Each company was required to determine its environmental liability more accurately through a corporate-wide environmental assessment program.

Initially, environmental auditing usually meant environmental compliance auditing. Audits were conducted to ascertain whether a facility was in compliance with applicable environmental laws. Around 1979, EPA began promoting environmental auditing. Consultants saw the benefits of environmental auditing of industries that were bewildered by the explosion of complex environmental regulations and that needed third-party verification of compliance status. A large number of parties entered the environmental auditing business with different objectives. The rapid increase in the conduct of environmental audits, without any standardized protocol, produced audits with widely varying quality, comprehensiveness, and utility.

Though risk-based auditing was encouraged by CERCLA's strict liability provision, and the requirements for financial assurance under RCRA and the corrective action assurance under the Hazardous and Solid Waste Amendments (HSWA), it was the Superfund Amendments and Reauthorization Act's (SARA's) innocent landowner defense that provided the real boost. Driven mainly by concerns about financial liability from hazardous waste disposal practices under CERCLA, SARA, and emerging state laws, property owners, sellers, buyers, and lenders learned



the value of liability control. The consulting community responded enthusiastically to the need for these assessments. ESA quickly became the predominant environmental audit activity. Compliance audits were still completed, but their numbers were small by comparison.

## **2.2. ESA Standards**

Initially, no standardized protocol existed for the performance of ESAs. Later, various agencies and organizations developed different ESA standards according to their needs to reduce liability and to protect the value of property investments.<sup>1</sup> Each *standard* is discussed below.

**2.2.1. Non-ASTM Standards:** Several non-ASTM standards were designed to perform environmental site assessments. The most important of these are summarized below.

**2.2.1.1. Agency for Toxic Substance and Disease Registry (ATSDR) Standard:** Under SARA, ATSDR was mandated to conduct health assessments within strict time frames for each site on or proposed for the U.S. Environmental Protection Agency's National Priorities List (NPL), establish priority lists of hazardous substances at Superfund sites, and produce toxicological profiles for each substance on this list. Before 1986, ATSDR conducted health assessments only in response to requests from the EPA. Under the amendments to CERCLA section 104(l), the responsibility to conduct health assessments at all NPL sites became mandatory.

ATSDR developed *Environmental Data Needed for Public Health Assessments: A Guidance Manual* (ATSDR 1994) to guide the performance of public health assessments. According to this guidance document, information required in an assessment includes site identifiers, site history, site geographic and demographic data, land use descriptions, relationships to nearby communities, hazardous substances present at the site, exposure pathways (e.g., soil, surface water, sediment, groundwater, air, and food-chain), identification of physical hazards, and available analytical sampling data. The manual guides the integration of environmental sampling results, health outcome data, and community concerns in the evaluation of the health implications of hazardous substances released into the environment.

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<sup>1</sup> Additionally, several organizations were established to certify environmental site assessors and auditors.

2.2.1.2. *Standard Operating Practice (SOP) Guidance:* The National Registry of Environmental Professionals, Florida Environmental Assessors Association, and National Association of Environmental Assessors issued a SOP Guidance document on June 8, 1992 (SOP 1992). The primary purpose of this guidance was to define the minimum scope of inquiry and methodology for the performance of a Phase I ESA. The secondary purpose of this guidance document was to identify other potential sources and evidence indicating the presence of contamination that was not covered under CERCLA/SARA, including petroleum products and other substances.

Tasks to be performed according to this guidance documents included review of existing records (e.g., maps, aerial photographs, and regulatory agency documents such as NPL, CERCLIS, FINDS, ERNS, TSD, Local Fire Department, Local Health Department, etc.) followed by a site reconnaissance in which an inspection of the site is conducted to determine possible sources of contamination. Before, during, and after site reconnaissance, interviews may be conducted with property owners, facility operators, adjacent property owners and operators, local government officials, and state and federal regulatory officials to augment site assessment findings. Finally, a report evaluating the condition of the property and characterization of pollutant releases is prepared.

2.2.1.3. *AGWSE Standard:* The Association of Ground Water Scientists and Engineers (AGWSE 1992) issued a guidance document for performing environmental site assessments. The document was intended to provide guidance to parties involved in a property transaction with a wide array of information that may be sought about a property. Besides regulatory and public records information, this guidance document inquired about geological and hydrological information, receptor data, site history, potential environmental problems associated with the site and adjacent sites, visual disturbances at and adjacent property, and information on underground storage tanks, lead, asbestos, drinking water sources, urea formaldehyde foam insulation, chemical uses, and storage, treatment and disposal areas.

Standards for four different land use scenarios were developed: vacant land, agricultural land, commercial land with improvements, and industrial land with improvements. AGWSE did not

offer recommendations regarding the scope of site assessment, but attempted instead to provide the user with tools to design his or her own scope of work. The assessors could select a few or all of the items recommended, depending on the goal of the assessment.

2.2.1.4. *ASCE Standard:* In 1996, the American Society of Civil Engineers (ASCE) published a guidance manual on conducting of environmental site investigations. This manual prescribed ESA actions beyond the traditional assessment phase and included risk management activities. This standard includes four phases of ESA: Phase I (Preliminary Site Assessment); Phase II (Site Investigation); Phase III (Remedial Investigation); and Phase IV (Remedial Planning, Design, and Implementation).

The work in Phase I involves the review of site-specific information, a site walkover, and interviews with people familiar with site operations and with agency personnel knowledgeable of the facility's compliance with environmental regulations. Phase II work generally involves intrusive testing along with laboratory analysis. The media to be tested depend on site specific conditions identified during Phase I. Phase III involves the collection of data defining the areal extent of contamination, its mobility, and potential risk to human health and the environment. Phase IV involves remedial planning such as evaluating treatment alternatives based on their feasibility for implementation, development of design documents, and implementation of the corrective action plan.

2.2.1.5. *International Standards:* Environmental site assessments are becoming more popular beyond U.S. borders as well. Their increasing popularity motivated the International Organization for Standardization (ISO), Technical Committee 207, to develop a standardized environmental site assessment process (ISO 14015) for use worldwide (Stec and Rabac 1995). This standard is still under development.

2.2.1.6. *Private Sector Manuals and Texts:* In addition to a number of government and professional organization standards and guidance manuals, guidelines developed by individuals were published. Some of these include Marburg Associates and Parkin (1991), Hess (1993), Sara (1994), Cahill and Kane (1994), Cahill (1996), and Cooper (1996). In addition, various texts

have been written on the subject of ESAs. A few of these are Haines and Stakhiv (1986, 1990), Chechile and Carlisle (1991), Lind, Nathwani, and Siddall (1991), Geweke (1992), Shindeldecker (1992), Hallenbeck (1993), Cothorn (1993), Asante-Duah (1993), Focht (1995), Mast (1995), Graham and Wiener (1995), and Kumamoto (1996).

**2.2.2. ASTM Standards:** To increase consistency and improve the quality of environmental site assessments, in early 1990, various segments of the real estate community joined under the auspices of the American Society for Testing Materials (ASTM) to form a committee on environmental assessments in commercial real estate transactions to clarify good commercial practice for performing Phase I environmental site assessments that satisfied the due diligence defense. The American Society for Testing and Materials (ASTM) published two guidance documents, *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process (E 1527 - 93)* and *Standard Practice for Environmental Site Assessments: Transaction Screen Process (E 1528 - 93)* to define good commercial and customary practice in the United States for conducting a high quality standardized environmental site assessment of a parcel of commercial real estate within the scope of CERCLA and petroleum products. Both practices are intended to permit a user to satisfy one of the requirements for the innocent landowner defense to CERCLA liability. A summary of each standard is presented next.

**2.2.2.1. ASTM E 1527-93: Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process:** Phase I site assessments are used to identify the presence of hazardous substances or petroleum products on a property under conditions that indicate an existing release, past release, or threat of release to structures, soil, groundwater, or surface water. Phase I site assessments have four components. The first component is a review of existing records (e.g., maps, photographs, and regulatory agency documents such as permits, enforcement actions, citizen complaints, and inspection reports) to gain familiarity with the property and identify possible releases. This is typically followed by a site reconnaissance in which an inspection of the site is conducted to more fully record conditions at the site and to characterize releases. Before, during, and after the site reconnaissance, interviews may be conducted with the property owners, facility operators, adjacent property owners and operators,

local government officials, and state and federal regulatory officials to augment the site assessment findings. Finally, a report that evaluates the condition of the property and characterizes pollutant releases is prepared.

*2.2.2.2. ASTM E 1528-93: Standard Practice for Environmental Site Assessments: Transaction Screen Process:* The purpose of the transaction screen is to qualify for the innocent landowner defense against CERCLA liability. To be eligible, the purchasing party must demonstrate that it has made a good-faith effort to discover past releases for which it would otherwise be held liable if the releases later were proven to pose unacceptable risks to human health or the environment. The transaction screen process consists of questioning knowledgeable persons such as current property owners and occupants about site conditions and history, verifying interview information during subsequent site visits, and further verifying the results of the previous two efforts by subsequently researching existing government and historical archival sources. If this initial inquiry provides suspicion that there may be releases at the site that may pose unacceptable risk to human health or the environment, a full Phase I environmental site assessment may be required.

*2.2.2.3. ASTM E 1739-95: Standard Practice for Risk-Based Corrective Action Applied to Petroleum Release Sites:* In November 1995, ASTM promulgated a final standard entitled "Risk-Based Corrective Action (RBCA) Applied at Petroleum Release Sites" that replaced the emergency standard promulgated 18 months earlier (ASTM ES 38). Risk-based corrective action is a generic term for corrective action strategies that categorize sites according to risk and serves as a decision-making aid to select appropriate actions to protect human health and environment. With this process, regulators can make sound, quick, and consistent management decisions using a three-tiered approach in which assessment and remediation activities are appropriately tailored to site-specific conditions and risk.

- Tier 1 is a qualitative risk-assessment based on general site assessment information to identify obvious environmental impacts, potentially affected sensitive receptors, significant exposure pathways, and likely adverse consequences of exposure.

Qualitative hazard assessment is done for all exposure pathways. The assumptions used for assessing risk under Tier 1 are conservative.

- If the decision-maker believes that a more rigorous risk assessment using site-specific information will produce greater savings in remediation costs, then he or she may opt to conduct a Tier 2 site assessment. In Tier 2, site-specific data are utilized to determine appropriate risk-based actions. In most cases, only a limited number of pathways, exposure scenarios, and chemicals are considered, since many are eliminated from consideration during Tier 1 evaluation. The reasonable maximum site-specific impact is evaluated using site-specific characterization and monitoring data, conservative projections of expected levels of contaminants after treatment, and potential plume migration and reasonable maximum exposure scenarios.
- Tier 3 site assessments may be conducted if the assessor believes that sufficient further cost savings may result. More sophisticated mathematical models are used to describe the fate and transport of contaminants in the environment and to predict exposure point concentrations at receptors. Monte Carlo simulation analyses may also be used to predict statistical distributions of exposures and risks, which can be used to define remediation goals and criteria.

It is important to note that the goal of all three tiers is to achieve similar levels of protection. The difference is that, in moving to higher tiers, the user is able to develop more cost-effective action plans by replacing the conservative assumptions of earlier tiers with more realistic site-specific assumptions.

2.2.2.4. *ASTM E 1903-97: ASTM Standard for Phase II Environmental Site Assessments Process*: The primary objective of conducting Phase II ESAs is to evaluate recognized environmental conditions identified during Phase I ESA investigations for the purpose of providing sufficient information regarding the nature and extent of contamination so as to assist making informed decisions about the need for remediation.

Under this assessment, the assessor first reviews all available information to identify those characteristics that constitute recognized environmental condition(s). In addition, the assessor evaluates the potential distribution of hazardous substances at the site, identifies the appropriate sampling locations, and selects appropriate sampling and analytical methodologies. The assessor uses field screening and field analytical techniques for qualitative and quantitative confirmation of the presence of contaminants. The assessor is obligated to report observations from a Phase II ESA to a government entity or a third party.

2.2.3. *Problems Associated with the Standards:* Organizations perform environmental site assessments for different reasons and follow different standards to perform them. Several problems can be identified with each of these standards, however.

- (1) *Comprehensiveness:* The standards are not comprehensive enough to describe a complete picture of the risk situation. Five essential components – a source of potential releases, the presence of a release, a pathway of contaminant migration, an exposed receptor, and an adverse response in the receptor caused by exposure to the release – have to be present for risk to exist. Without these five elements, it would be difficult to conclude that a recognized environmental condition exists. Most standards, however, do not require characterization of all five components.
- (2) *Detail:* None of the standards provides sufficient detail to adequately guide an environmental site assessment. For example, none inquire into the site's enforcement history or into the regional meteorological setting. Moreover, most standards only address a few of the types of contaminant sources that can be found at a site.
- (3) *Organization:* Information regarding federal, state, local, and on-site records; site reconnaissance; and interviews of owners, operators, employees, neighbors, and regulatory officials required by these standards are not sufficiently organized to efficiently guide the conduct of an assessment. The ESA process should be organized in such a way that it will lead the assessor to answer all site-relevant questions in an efficient manner. Since the information required to follow the standards is not prompted in an

efficient way, it makes the work of the assessor much more difficult. As a result, the whole process becomes so time-consuming that the cost to perform the ESA becomes unnecessarily expensive.

Because of these problems, the environmental site assessments that are performed using these standards may result in the failure to qualify for indemnification from CERCLA liability, inadequate or unnecessary cleanup, and a false sense of confidence. To address these problems, an environmental site assessment standard that is comprehensive enough to address all five elements of risk, detailed enough to actually portray the actual condition of the site, and organized enough to perform the ESA efficiently is sorely needed.

In addition to problems with existing standards, there are problems associated with the means of conducting environmental site assessments. ESAs are performed either manually (e.g., using paper checklists and notebooks) or electronically (using software programs). The manual ESA process involves much repetition and are therefore quite time consuming. For example, a manually performed Phase I ESA can take from a few weeks to several months from the start of data collection until a final report is delivered. To speed up the assessment process, several software packages have been developed. However, these also have several problems. First, they are phase specific and therefore require that data collected during a Phase I investigations be reentered before a Phase II investigation can begin. Since both manual and electronic ESA protocols are based on published standards, they inherit their problems as well.

Problems with the major standards are summarized in the following table.

Areas of Concern	Standards				
	ATSDR	SOP	ASGWE	ASCE	ASTM
Type of Assessment	Health	Phase I	Phase I for four land use scenarios	Phase I, Phase II, Phase III	Phase I, Phase II
Main Focus	Health implications	Pollutant presence	Geologic and hydrologic information	Identify liability	Determine if REC exists; if so, risk is assessed



Areas of Concern	Standards				
	ATSDR	SOP	ASGWE	ASCE	ASTM
Includes enforcement history	No	Limited	Limited	Yes	No
Number of sources considered	Few	Few	Few	Few	Few
Consider receptors	Yes	No	Yes	Yes	No
Considers receptor responses	Yes	No	No	Yes	No
Includes meteorological information	No	No	No	No	No
Includes regional hydrological information	No	Yes	Yes	Yes	No
Includes regional hydrogeological information	No	Yes	Yes	Yes	Yes
Expensive	Yes	Yes	Yes	Yes	Yes

### 2.3. ESA Methodologies

Environmental site assessments have been performed manually for the last 20 years or so. Often, they have been guided by a checklist developed by individual practitioners (e.g., Hess 1993; Cooper 1996), in accordance with numerous guidance documents, promulgated regulations, or standards issued by independent organizations such as AGWSE (1992), ASTM (1993; 1994; 1997), and ASCE (1996). More recently, attempts have been made to automate the site assessment processes. Both manual and automated methods have deficiencies.

**2.3.1. Traditional Manual Method:** According to this method, the assessor makes a checklist of all the information he/she needs for performing ESA. While designing the checklist, the assessor makes sure that the checklist is consistent with the requirements described in ASTM or other standards. He/she then gathers that information by reviewing regulatory and public records, inspecting the site and interviewing with various knowledgeable persons who are familiar with the site. He/she records the information that is required according to the checklist. Once, the assessor has gathered all the information, he/she prepares a report. The report contains all the findings of the investigation about the site.

2.3.1.1. *Problems Using the Traditional Method:* Most of the problems associated with this method are the same as the problems associated with the standards upon which they are based.

- (1) *Time-consuming:* A manual ESA process often involves redundancy of effort. Data is collected manually by taking notes and photographs; taping audio; collecting and measuring the samples; analyzing the data and information; and preparing the reports (draft, revision, and final). It is not uncommon that the same source of information is consulted multiple times before all required data is obtained.
- (2) *User-friendliness:* The whole process is complicated enough to collect all the information efficiently. Though checklists dictate which information is required, they do not order the information in a meaningful way. Thus, the assessor collects information in an indiscriminate fashion. Later, the assessor must reorganize the information for presentation in a report.
- (3) *Consistency:* Since the checklists are developed by different practitioners to meet their own objectives, the assessment performed using this process is not consistent. As a result, the quality of the assessment varies.
- (4) *Organization:* One of the main problem with this process is, the checklist is not organized enough to assist the assessor to reach a justifiable conclusion regarding hazards at the site. As a result, no matter how insignificant the hazard is at a site, one has to need the opinion of an experienced assessor to perform the assessment.
- (5) *Quality:* If the assessment is done strictly based on a checklist, the assessor might ignore other features that are unique to the site. A lower quality assessment may result.
- (6) *Expense:* The lengthy delay and the requirements of an experienced assessor can make the site assessment process very expensive.

2.3.2. ***Automated Software Systems:*** To avoid many of the problems (speed, consistency, user-friendliness) discussed above, there have been several efforts to automate the site

assessment process. Several software packages are available to perform Phase I, Phase II, and other site assessments.

2.3.2.1. *Phase I ESA Software:* Two popular software packages – “Softshell” and “Site Assessment” are available to perform Phase I ESAs.

2.3.2.1.1. Evaluation of Softshell: This software was developed by W.J.Truby and is approved by the National Registry of Environmental Professionals. The software, based on ASTM standards, was written using Microsoft Visual Basic 4.0<sup>®</sup>. Windows 3.1 or higher is required to run this software. The cost of this software is \$695.00. The information required for performing a Phase I ESA is divided into four main sections – regulatory records, land use data, site reconnaissance description and interviews, and report components. Within each of these sections are several sub-sections. The sub-sections of regulatory records include information on the identification of the owner and operator of the property and local, state, and federal records. The land use section addresses the current and past land uses of the property. The site reconnaissance and interview section includes information about hazardous substances such as PCBs, asbestos, radon, lead, stored chemicals, pipelines, spills or leaks, air emission, wastes, agricultural chemicals, MSDSs (Material Safety Data Sheets), interviews of personnel, physical layout, and other observations. Each sub-section includes at least one question. Free form text fields are used to enter answers. In all, there are 40 questions. After the assessor answers all questions relevant to the site, the software will generate a pre-formatted report.

2.3.2.1.2. Evaluation of “Site Assessment”: “Site Assessment” software produces Phase I and transaction screening reports faster and easier than the Softshell. The software was developed by environmental professionals at McNeill Software. The computer requirements to run this software are Windows 3.1 or Windows 95, 4 MB RAM, and 8 MB of hard disk space. “Site Assessment” software solicits information about the legal description and location of the site; site and vicinity characteristics; descriptions of structures, roads, improvements, present and past land use on and adjoining site; federal and regulatory records; site reconnaissance and interviews; future land use scenarios; descriptions of storage tanks; and characteristics of hazardous substances, solid wastes, hazardous wastes, storm water runoff, and air emissions.

This software is comprised with several checklists that are used as a guide for site observations and record gathering process. Each checklist includes several questions. The user simply answer questions with yes, no, or unknown. Altogether, the software contains more than 500 questions. The user can skip questions that are not applicable to the site. The software combines a word processor with a database containing huge libraries of expert, customizable site assessment report text. It allows the assessor to edit the text within the reports directly or use another word processor to include the text beyond provided by the libraries. The average environmental assessment report is 40-60 pages.

2.3.2.1.3. Problems Associated with Phase I ESA Software Systems: The following section summarizes the problems related to both automated Phase I ESA software systems.

- (1) Comprehensiveness: "Softshell" is strictly based on ASTM standard. "Site Assessment" incorporates ASTM as well s other standards. As a result, it is little bit more comprehensives than Softshell. However, it is not comprehensive enough to identify the potential responsible parties at the site. Though both software systems inquire about the present and past land uses of the property, they do not address regional meteorology, regional geology, or transportation structures. "Site Assessment" includes a few more sources than "Softshell." However, it does not go into require a sufficiently detailed description of sources. For example, though it inquires about a tank's registration number, stored chemicals, and leaks, it does not ask anything about its current activity status, physical condition, pollution prevention methods, or enforcement history. Finally, as discussed earlier, a release source, actual release, pathways of migration, receptor, and response) must be present before a recognized environmental condition can exist. Though both "Softshell" and "Site Assessment" software ask questions about the sources of releases and pathways of migration, they do not ask about receptors and their responses to contaminant exposures, which, of course, makes it difficult to reach a conclusion about whether a recognized environmental condition exists.

- (2) User-friendliness: The "Site Assessment" software system is more user-friendly than "Softshell." In Softshell, the assessor must manually enter all answers to the questions. In "Site Assessment," the answers to most questions are pre-entered (e.g., Yes, No, and Unknown). However, "Site Assessment" does not allow the assessor to input text other than those already provided.
- (3) Organization: Neither "Softshell" nor "Site Assessment" software systems is sufficiently organized to lead the assessor to the appropriate forms applicable to the site: the assessor has to decide for himself or herself which information is important.

In addition, neither system (1) allows multimedia (video and audio) capture; (2) generates multimedia reports; (3) performs decision-support; or (4) has GPS and GIS systems built-in with their programs to display the maps and hazards.

2.3.2.2. *Phase II ESA Software:* Several risk assessment programs are available in the market for conducting Phase II environmental site assessments. Three of the most popular are described briefly below.

2.3.2.2.1. APIDSS: The American Petroleum Institute (API) exposure and risk assessment Decision Support System (DSS) is a tool that can estimate site-specific risks at sites contaminated by petroleum hydrocarbons and other contaminants (APIDSS 1994). It consists of four modules.

- Development of Risk Scenario Module: In this module, the user identifies chemicals of concern, relevant uptake routes, and the specific models to estimate receptor point concentrations.
- Fate and Transport Module: This module includes models to simulate contaminant fate and transport from source to receptor, and receptor point concentrations. The models address atmospheric emission and dispersion, and unsaturated and saturated zone contaminant transport.
- Chemical Intake and Risk Calculation Module. This module uses the computed receptor point concentrations or user-entered concentrations to estimate chemical intake by

human receptors for several different exposure routes. These routes include ingestion of contaminated water and soil, inhalation of air containing volatile contaminants, and dermal contact with contaminated soil and water. This module estimates carcinogenic risk and non-carcinogenic effects (hazard index).

- Risk Presentation Module. This module uses Microsoft Excel<sup>®</sup> to present the estimated chemical intakes, carcinogenic risks and the hazard indices. Several graphical and tabular options for presentation of results are available to the user.

The Decision Support System (DSS) consists of compiled KnowledgePro<sup>®</sup> and FORTRAN codes, ASCII files, and Microsoft Excel<sup>®</sup> macros. The user needs not be familiar with KnowledgePro<sup>®</sup> to use DSS.

2.3.2.2.2. RISC: British Petroleum's (BP) Risk-Integrated Software for Cleanups (RISC) is a Windows based program that can be used to (1) estimate human risk from exposure to contaminated media, (2) estimate risk-based cleanup levels in various media, and (3) perform simple fate and transport modeling (RISC 1998). It allows the user to follow the ASTM tiered approach by utilizing a spreadsheet based on the ASTM algorithms for tier 1, the embedded fate and transport models for Tier 2, and the Monte Carlo option for Tier 3. RISC allows the user to:

- choose chemicals of concern from a library of 72 chemicals (the user can add or delete chemicals from the library);
- perform a cumulative risk assessment for two exposure scenarios (with up to nine exposure pathways each);
- use a Microsoft Word<sup>®</sup> template to write a risk-based closure report for regulatory submission;
- use an embedded tool to estimate average, 95<sup>th</sup> upper confidence limit, and weight-averaged concentrations for a set of parameter values; and
- print or save tables, charts, and figures.

The hardware requirements for this software are IBM 486 or compatible computer, 10 MB RAM, and 8 MB hard drive space. The software requirement is Microsoft Windows<sup>®</sup> 3.1 or Windows<sup>®</sup> 95. Microsoft Excel<sup>®</sup> 7.0 and Microsoft Word<sup>®</sup> 5.0 are needed to access two optional packages.

2.3.2.2.3. RiskEZ: Pinyon Software developed a software program called RiskEZ for Windows<sup>®</sup> to perform human health risk assessments in accordance with standard EPA guidance (RiskEZ 1997). It can calculate both excess lifetime cancer risks and noncancer hazard quotients resulting from exposure to chemicals in the environment. The assessment process involves the following steps.

- Input average exposure concentrations.
- Define scenarios [a single exposure scenario consists of a population, location, exposure pathway (source medium, exposure route, and exposure medium), effect (cancer, noncancer), and exposure period].
- Review exposure equations (RiskEZ contains standard EPA risk equations for 27 predefined exposure pathways. The user can modify the standard equations using the Equation Editor.)
- Enter exposure parameter values (default values for over 70 parameters are included).
- Check toxicity values (from EPA's IRIS and HEAST databases as well as from Cal/EPA).
- Characterize risk.
- Generate reports (RiskEZ contains more than 40 pre-defined reports. It uses a runtime copy of Borland International's ReportSmith report writer).

The system requirements required for RiskEZ are Windows 3.1<sup>®</sup> or later, IBM PC compatible with a 486-50 or higher processor computer, 6 MB of RAM (8 MB Recommended), and 20 MB free hard disk space.

2.3.2.2.4. Deficiencies of these Software Systems:

- (1) Phase-Specific: APIDSS, RiskEZ, and RISC were developed to perform only Phase II environmental site assessments. Therefore, the data that were collected during Phase I ESAs must be re-entered.

- (2) **User-Friendliness:** APIDSS is not as user-friendly as other two. Since, it does not have context-sensitive help features, an experienced assessor is required to run it.
- (3) **Pathways of Exposure:** Both APIDSS and RISC software systems contain a limited number of pathways of exposure. RiskEZ has many more pathways of exposure. However, these mainly include only direct exposures to the receptor (i.e., they do not include fate and transport models).
- (4) **Chemicals of Concern:** The number of chemicals present in the chemical database for each software system is much smaller than in IRIS. However, new chemicals and chemical attributes can be added by editing the databases.
- (5) **Reports:** APIDSS is able to generate both tables and graphs for chemical intakes, carcinogenic risks, and the hazard indices. However, it cannot generate text-formatted reports. Both RISC and RiskEZ are able to generate text-formatted reports with attached tables and graphs.
- (6) **None of the Phase II ESA software systems (1) allow multimedia (video and audio) capture; (2) generate multimedia reports; (3) perform any decision-support; or (4) include GPS and GIS capabilities to display the maps of site features and hazards.**

2.3.2.3. *Other ESA Software Systems:* Other software systems are available to perform different types of site assessments. The following information was collected from articles printed from RiskWorld's website (Tec-Com, Inc. 1999).

2.3.2.3.1. **RMP 99 Assistant:** This is a Windows-based program designed to inform risk management planning. It confirms release duration, identify migration factors, and describe the release point. Its features include help in calculating the toxic endpoint calculations, defining a release scenario, and processing hazard analyses.

2.3.2.3.2. **SitePro:** Environmental Software developed *SitePro*, which helps environmental professionals to characterize, manage, remediate, and restore environmental sites more quickly and comprehensively.



2.3.2.3.3. RIP: Golder Associates developed this risk assessment software. RIP is a flexible, probabilistic fate and transport model originally developed for making long-term risk assessments of radioactive waste repositories.

2.3.2.3.4. RBCA Tool Kit: RBCA Tool Kit for chemical release is a comprehensive modeling and risk assessment/characterization software package for Tier I and Tier II RBCA evaluations for chemical release sites. The Tool Kit combines contaminant transport models and risk assessment tools to calculate baseline risk levels and derive risk-based cleanup standards for soil, groundwater, surface water and air exposure pathways.

2.3.2.3.5. Human Exposure Assessment Modeling Software Toolbox: This program is useful in the estimation of human exposure to chemicals from airborne and dermal routes. Microsoft Excel<sup>®</sup> and Microsoft Basic<sup>®</sup> were used to develop this toolbox.

2.3.2.3.6. CAMEO: The National Safety Council developed CAMEO which includes (1) a safety and emergency response database to track chemical inventories and to prepare emergency plans for facilities and chemicals in transits, (2) an emergency air dispersion model, ALOHA to estimate the endpoints of toxic plumes, and (3) a mapping application to analyze spatial data spatially and assess risk to vulnerable populations.

2.3.2.3.7. SmartRisk: Pioneer Technologies Corporation developed SmartRisk. It is a complete multi-chemical, multi-pathway risk assessment modeling package for Windows.

In addition, other risk assessment software packages are available in the market include *RISKMAN* (Integrated risk assessment package), *PHAWorks* for Windows (process hazard analyses), *S-Plus* (environmental statistics and quantitative risk assessment), *RAMAS*<sup>®</sup> (ecology, conservation biology, wildlife management and public health risk analysis tool), *SADA* (integrates visualization modules with geospatial analysis, statistical analysis, human risk assessment, cost/benefit analysis, sampling design and decision analysis).

Most of these software systems are designed to perform site-specific assessments, though they are closely related to Phase II assessment software systems. Thus, they are neither

comprehensive nor detail to be used for all different scenarios for the site. Most of them discussed about the releases and the risk associated with the releases. But they do not include any legal, environmental setting and source information. Besides, they don't generate report. In addition, they don't allow multimedia capture, perform any decision-support; or include GPS and GIS capabilities to display the maps of site features and hazards.

## **CHAPTER 3**

### **EESASS DESIGN**

#### **3.1. Introduction**

EESASS (Enhanced Environmental Site Assessment Software System) is a collection of computer software routines that work together to assist the user in performing an environmental site assessments and subsequently managing environmental risks present at a chemically-contaminated site. EESASS is a component of E-FAST. The following sections described the design of EESASS.

#### **3.2. Philosophy of EESASS Protocol**

Four major categories of information are required to identify environmental hazard and then assess risk at the site. This following discussion is taken from Focht (1995) and is an adaptation of the National Academy of Sciences risk analysis paradigm (NAS 1983).

The first category concerns the sources of pollutant releases. Source characterization requires information about the number of releases and their locations, the types of units or activities that were the source of the releases, the aerial extent of releases, the duration of releases, and the identities and the quantities of pollutants released.

The second category concerns the receptors that may be exposed to the pollutant releases. These may be both human and ecological receptors. Both current and future land use scenarios must be considered. Receptors may be located on-site (e.g., workers, customers, visitors, and subsequent landowners) and off-site (e.g., adjacent property owners or renters, visitors, commuters). Demographic information on human receptors such as number, location, age, weight, gender, race and ethnicity, socioeconomic status, lifestyle, dietary practice, health status, and frequency and period of time spent near the site; are all important to risk calculations.

The third category concerns the environmental pathways by which pollutants can migrate from the release sources to bioreceptors. Exposure may occur both on-site and off-site, at frequencies which may be single event, intermittent or continuous. Exposure can also occur through several environmental media, such as surface water, ground water, air, surface soil, subsurface soil, and sediment. Intake pathways include oral ingestion, inhalation, and dermal uptake. Routes of exposure include the mouth (such as finfish and shellfish, dairy products, meat, grains and vegetables and by ingesting soil), water (via swimming, drinking, and showering), air (via inhalation of suspended particulates, aerosols, and volatiles), and skin (via direct soil and water contact). Exposure information must also include exposure frequencies and duration, and cumulative exposures such as from multiple pollutants via multiple pathways over multiple exposure events. This exposure information is used to calculate doses of pollutants to maximum exposed individual receptors in a step of risk assessment known as exposure assessment.

The final category concerns the adverse health and environmental responses that exposure to pollutants may cause in receptors. These include both threshold (systemic toxic) and non-threshold (carcinogenic) effects. By consulting various databases, such as the EPA's Integrated Risk Information System (IRIS), information on responses specific to each receptor, exposure pathway, and toxicological endpoint can be identified. Responses must include consideration of acute, subchronic and chronic exposure duration and cumulative exposures. Also important are the inherent toxicity of each pollutant, the absorption coefficients, and the choice of endpoint. This information is considered in developing toxicological profiles of each pollutant in what is called toxicity or dose-response assessments. The exposure and toxicity assessment data is combined to estimate risks to receptors in what is known as risk characterization. Calculated risk estimates are then compared to acceptable risk standards such as hazard indices (for systemic toxicants) or acceptable cancer risks (for carcinogens) to determine whether risk mitigation is required.

Environmental site assessments are conducted in order to aid environmental managers in their decision making about what, if anything, needs to be done to reduce risk to human health or the environment due to exposure of bioreceptors to releases of pollutants in the environment. Risk-

based decision-making is an important component of rational risk management. Risk management efficiency is improved when resources are devoted to reducing only those risks that are worth reducing. Efficient risk management, therefore, requires accurate risk estimates. Since risk assessments can be expensive, it is important to expend resources to investigate only those hazards (causal chains from toxicant release to adverse effect in a receptor) that have been shown to have a potential to pose unacceptable risk. Environmental site assessments must identify significant hazards to help ensure that subsequent risk assessments will be conducted efficiently.

### **3.3. Design of Enhanced Environmental Site Assessment Protocol**

One of the main objectives of this research is to develop a standard environmental site assessment protocol which will resolve the problems associated with different ESA standards and will contain enough information so that the assessor can accurately, effectively and efficiently determine the condition of the property. To do so, the project protocol adopts ASTM standards E 1527, E 1528, & E 1903 as the basis for the design of EESASS protocol. However, EESASS goes beyond the standards by incorporating other site assessment standards, guidance documents, publications and lessons learned in the field by site assessors into the design. For example, EESASS's modeling of exposures and risks are based on the risk-based corrective action protocol defined by ASTM E 1729 and the contaminant transport models included in the American Petroleum Institute Decision Support System (APIDSS) package.

The enhanced environmental site assessment protocol is designed to perform three types of assessments - (1) Enhanced Phase I ESA; (2) Enhanced Phase II ESA; and (3) Enhanced Phase III ESA. There are a couple of reasons why the word "Enhanced" is included in front of each assessment. None of the ASTM standards mention the requirements of (a) receptors that may be exposed due to the releases, and (b) environmental sampling. The objectives and the components of each phase of ESAs are summarized in the following section.

**3.3.1. Enhanced Phase I Environmental Site Assessment:** An enhanced Phase I ESA is conducted to qualitatively identify hazards that exist at a site due to environmental releases of

toxicants. A hazard exists if there is a demonstrated potential linkage between a source of toxicants (e.g., a waste management unit such as a landfill), a release of the toxicants from the source to the environment (either directly or via an area of contamination outside of the source), a pathway of migration of the released toxicants through the environment to a human receptor, the exposure of the receptor to the released toxicants, the intake of the toxicants into the body of the receptor via one or more intake routes, and the production of an adverse effect that threatens the health of the receptor.

Enhanced Phase I ESA is comprised of four distinct modules: legal description, environmental setting, source characterization, and hazard identification. The following section summarized those four modules.

- (1) **Legal Description:** The legal section prompts the input of information about the legal status and description of the property, its location and size, its owner(s) and operator(s), and its operational and regulatory history. It also prompts for relevant information about the client, the assessor, and the assessment.
- (2) **Environmental Setting:** The environmental setting section prompts the input of information about current, past, and future land uses. Other forms inquire about the meteorology, hydrology, hydrogeology, and geology of the region in which the site is located. Remaining forms prompt input of information concerning archeological, historical, and recreational resources as well as threatened and endangered species and critical habitat(s) that may be located in close proximity.
- (3) **Source Information:** The source section prompts the input of information about the material management units, and waste management units, buildings, and other structures that are or were present on the site that are or were sources of toxicants releases. This information includes operational history (e.g., dates of installation and types of material or waste handled), design (e.g., operating conditions and pollution prevention measures), and legal history (compliance inspections, enforcement actions, and corrective/remedial actions).

- (4) **Hazard Identification:** The hazard identification section prompts the input of information about toxicant releases (e.g., size, quantity, location, probable source(s), identities and quantities released, and pathways of likely migration through the environment) and about human receptors who may or could be exposed (only human receptors are addressed in Version 1.0 of EESASS). This section also includes information about on-site physical and weather conditions experienced during site reconnaissance. The objective of this section is to establish a causal relationship among release(s), source(s), pathway(s) of migration, exposed receptor(s), intake route(s), and response(s). A causal linkage among each of these elements indicates that a hazard is present.

**3.3.2. Enhanced Phase II Environmental Site Assessment:** A Phase II ESA is conducted only if a Phase I ESA has concluded that a hazard exists. The Phase II ESA assesses the risks at a contaminated site posed to receptors by hazards. An assessment of risk is necessary to justify the need for remediation; remediation is required only if the risk is high enough to be unacceptable. In other words, the magnitude of the threat must exceed a pre-defined threshold referred to as *de minimis* risk before corrective action is required.

In EESASS, the Phase II ESA can consider both proximal and distal exposures. For proximal exposures, risk is quantified for exposure by proximal receptors located directly adjacent to the sources that are releasing toxicants. This is a conservative exposure scenario since it assumes that no land use controls are in place that can prevent entry and exposure on site. For distal exposures, risk is quantified for indirect exposures that consider the transport of toxicants from the sources through one or more environmental media to a receptor. Consideration of distal exposures is particularly important if land use controls will be used to prevent access to the site. Land use control exposure scenarios are thus less conservative in that less risk management intervention may be required.

The enhanced Phase II ESA includes the same legal description, environmental setting, and source characterization sections used in Enhanced Phase I ESA, along with a risk assessment module that replaces the Enhanced Phase I ESAs "Hazard Identification" section. Like the

hazard form, the risk assessment section prompts the input of information characterizing releases, human receptors who may or could be exposed, and the physical site and weather conditions experienced during site reconnaissance. In addition to this information, the section prompts input of information concerning concentrations of released toxicants, additional site-specific information about environmental media and receptors, and the assessor's preferences for selection of exposure models contained within the EESASS risk calculation program. The environmental media that are addressable in EESASS are air, surface water, groundwater, and soil (sediment and food are not included). Equations for several intermedia transfers of toxicants are also included.<sup>2</sup> During risk assessment calculations, the program first determines the presence of a hazard at the site, and if one or more hazards exist, the program estimates the risk posed by these hazards. Finally, the program determines if the baseline risk is unacceptable, and if so, identifies those chemicals, sources, environmental media, and receptor intake routes that are contributing to the unacceptable risk.

**3.3.3 Enhanced Phase III Environmental Site Assessment:** An enhanced Phase III ESA is conducted to explore the efficacy of alternative risk management scenarios for reducing risk to acceptable levels. Individual risk management scenarios must be developed and tested for each receptor who is exposed to unacceptable risk.

The enhanced Phase III ESA includes all four sections of enhanced Phase II ESA plus an additional decision support section for selecting the risk reduction scenarios. The description of the decision support section is provided in the following section.

The decision support section prompts the input of the assessor's preferences for risk reduction. The assessor is given two sets of choices as to how risk management should proceed: hazard component intervention (three choices) and risk reduction method (four choices). The combination of these two sets produces 12 risk management alternatives.

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<sup>2</sup> Intermedia transfers of toxicants not included in EESASS version 1.0 are: (1) surface water to air, (2) air to surface water, (3) air to soil, (4) soil to surface water, (5) groundwater to surface water, and (6) surface water to groundwater. One single medium transfer equation is also not included in version 1.0 of EESASS: surface water transport. Chemical transport equations not included are: (1) DNAPLs in groundwater, (2) DNAPLs in surface water, and (3) LNAPLs in surface water. Table 4-1 showed all fate and transport models that are included in EESASS version 1.0.



In the first set of choices, the assessor can select whether risk management intervention is to be focused on the sources of contamination, pathways of migration, or receptor intake routes (referred to as hazard components in EESASS). The source remediation option investigates elimination (complete removal) or mitigation (partial removal) of the contributing sources (including areas of contamination). The migration pathway remediation option ignores sources and instead considers the complete or partial interruption of pathways of migration of toxicants from sources to the receptor. The intake remediation option investigates the effects of reducing exposure by controlling receptor intake routes. This third option involves only receptor behavior intervention, which can reduce risk without altering the environmental concentration of toxicants at the sources or interrupting contaminant pathways of migration.

The second set of choices afforded to the assessor by EESASS concerns alternative risk reduction scenarios. Four risk reduction alternatives (referred to as risk reduction components in EESASS) are available. In the “equal risk reduction” alternative, all sources/media/intakes (depending on the selection made above) to which a receptor is exposed are equally reduced until the cumulative residual risk is acceptable. In the “weighted average risk reduction” alternative, the risk associated with each source/medium/intake is reduced according to their relative (weighted) contribution to the cumulative risk. In the “worst case risk reduction” alternative, the sources/media/intakes are successively reduced (in decreasing order of risk contribution) to zero risk until the cumulative residual risk is reduced to an acceptable level. In the “assessor-specified risk reduction” alternative, the assessor manually specifies the percentage risk reduction for a particular source/medium/intake. The residual risk remaining after remediation will then be displayed. If not acceptable, the assessor can re-run the risk calculator with new values for risk reduction until the cumulative residual risk is acceptable.

Twelve combinations of these two sets of options are therefore possible. For example, the assessor could choose to explore the results of reducing risk using the worst-case approach in remediating sources. Alternatively, the assessor could choose to explore risk reduction using the specified reduction percentages for each migration pathway.

### **3.4. Automated Enhanced Environmental Site Assessment Protocol**

Enhanced Environmental Site Assessment Protocol can be made effective, accurate, and efficient through the use of a powerful handheld pen entry table computer augmented with a number of PC Card slots. The slots allow cards to capture video, images, GPS (Global Positioning System) time and position, audio, etc., in real time and store them in an object-oriented database. The availability of GPS, video and audio cards allow the site assessment to be documented in a multi-media fashion. This multi-media forms based system will work in tandem with a Geographic Information System (GIS) to provide the user with a portable, powerful, user-friendly environmental assessment decision tool that will not only allow site specific flexibility while maintaining comprehensibility but also will enhance the legal sufficiency of the site assessment data. The assessor does not require inputting the data in all of the forms. The software will lead the assessor to input the data in the appropriate forms that are specific for the site. At the end of inputting all the data, the software will be able to generate a plain text report or text report with embedded sound and video images with links to geographic information systems (GIS) maps and databases. The automated Enhanced Environmental Site Assessment Protocol is known as "EESASS" in this project.

### **3.5. Important Features of EESASS**

EESASS is designed to run on both desktop and notebook computers using a Microsoft Windows 95<sup>®</sup> operating system. The following section describes briefly a few of the major features of the EESASS software system.

- (1) **Data Entry Program:** EESASS contains a series of discreet graphical user interface (GUI) input forms to assist the user in entering data into EESASS. For version 1.0, 1054 GUI forms were developed for all three phases of EESASS using Microsoft Visual Basic 6.0<sup>®</sup>. Each form is a distinct GUI template, which may be composed of one or more pages (screens).
- (2) **Data Storage and Retrieval Program:** In EESASS, all data are stored and managed in a relational database built with Microsoft Access 97<sup>®</sup>. Data input by the assessor via GUI

input forms are stored in project-specific tables. In addition, four fixed tables reside in the relational database: chemical physical properties, chemical toxicity properties, soil physical properties, and receptor properties. Data in those tables are stored permanently; they are not modifiable by the user. Many GUI inputs are checked for errors before they are stored in database tables.

- (3) **Preliminary Risk Assessment Program:** In EESASS, the Phase II ESA can consider both proximal and distal exposures. For proximal exposures, risk is quantified for exposure of receptors located directly adjacent to the sources that are releasing toxicants. For distal exposures, risk is quantified for indirect exposures that consider the transport of toxicants from the sources through one or more environmental media to a receptor. Consideration of distal exposures is particularly important if land use controls will be used to prevent direct access to the site. EESASS adopts the equations used in the risk-based corrective action (RBCA) protocol defined by ASTM E 1729.
- (4) **Visualization and Decision Support Program:** EESASS utilizes ArcView 3.1<sup>®</sup> geographical information system (GIS) software to generate physical, environmental, and risk coverage. A customized menu and tool bar have been added to the ArcView<sup>®</sup> interface to make it easier to display coverage and conduct queries. ArcView<sup>®</sup> is also used to display the results of the decision support component of EESASS. EESASS accepts DynaMo<sup>®</sup> GIS data to store global positioning system (GPS) data during site reconnaissance.
- (5) **Reporting and Documentation Program:** EESASS uses Microsoft Visual Basic 6.0<sup>®</sup> to generate three types of reports: text only, text with graphics, and text with multimedia. The text with multimedia option is not available in EESASS version 1.0, but can be made available in subsequent versions. Reports are generated in HTML format with no option for pre-formatted page breaks. However, the assessor can edit the HTML report using any HTML compatible word processor to ensure that page breaks are placed properly.

### **3.6. Advantages of EESASS**

Enhanced Phase I ESA protocol incorporated information from ASTM standards, other guidance documents and publications and the lessons learned in the field practice by site assessors as well. As a result, the protocol is not only comprehensive, but also complete. It also goes into detail as much as possible while explaining each of the subjects in the protocol. It can be applied as a standard environmental site assessment tool in all different sites under different scenarios.

EESASS is much user-friendlier than any other ESA software systems available in the market. It adopts graphical user interface (GUI) as the basis for the design and development of the forms. There are 1054 forms in this software. The assessor does not have to input the data in all of the forms. The protocol is so well organized that the software will lead the assessor to input the data in those forms that are appropriate for the site. Due to this reason, the software does not require skilled assessor.

One of the unique features of this software is its ability to accept real-time data-entry features such as keyboards, mice, pen, video images, and global positioning system (GPS). After the completion of data entry, the software will generate a text report with embedded sound and video images, with links to geographic information system (GIS) maps and data tables. Thus, EESASS is faster than other existing processes that are used for performing ESA.

EESASS is not phase-specific. It is the only software system available that performs all different kinds of assessments under same packages i.e. the assessor does not need to reenter the same data for different type of assessment.

EESASS includes decision-support system to determine different risk reduction strategies for the site. No other ESA software includes such system.

EESASS includes 17 pairs of fate and transport models in its risk assessment process. It is much more than APIDSS and RISC. It also includes fate and transport models where the contaminant travels more than two mediums. None of the Phase II software systems include such a model.

EESASS includes one physical and one toxicological chemical database tables. It incorporates all the IRIS chemicals information in those tables.

EESASS is capable of not only assessing both the cancer and systemic risks but also displaying those risks graphically on a GIS display.

One of the unique features of EESASS is, it includes a module for error checking of all data entries to insure proper formatting and valid data values. It also includes default values for variables for which default values have been published in US EPA documents such as the *Exposure Factors Manual*, Volumes 1-3.

EESASS includes two different types of help features - context-sensitive help messages and help menu with contents, thus makes it user-friendlier than other existing software systems.

The initial cost of this whole system will be higher than the other existing system. However, it takes a shorter time to complete and does not require any skilled assessors. Therefore, EESASS will be cheaper in the long run.

## CHAPTER 4

### DEVELOPMENT OF EESASS

#### 4.1. Introduction

EESASS is designed as a hierarchical, modular system; that is, it is constructed in discrete parts so that it can be altered independently. EESASS is a *software system* composed of five *programs*, which are composed of *modules*, which are composed of *processes*, which are composed of *functions*, which are composed of *operations*. The five EESASS programs are:

- ◆ Data Entry Program (DEP)
- ◆ Data Storage and Retrieval Program (DSaRP)
- ◆ Preliminary Risk Assessment Program (PRAP)
- ◆ Visualization and Decision Support Program (VaDSP)
- ◆ Reporting and Documentation Program (RaDP)

A diagrammatic representation of the EESASS programs (double borders) and their interrelationships (arrows) is provided in Figure 4-1. Programmatic interfaces (rounded rectangles) are also shown. The DSaRP, with its associated database, is considered as the centerpiece of EESASS and therefore is surrounded by a triple border. Each of these programs is discussed in the following.

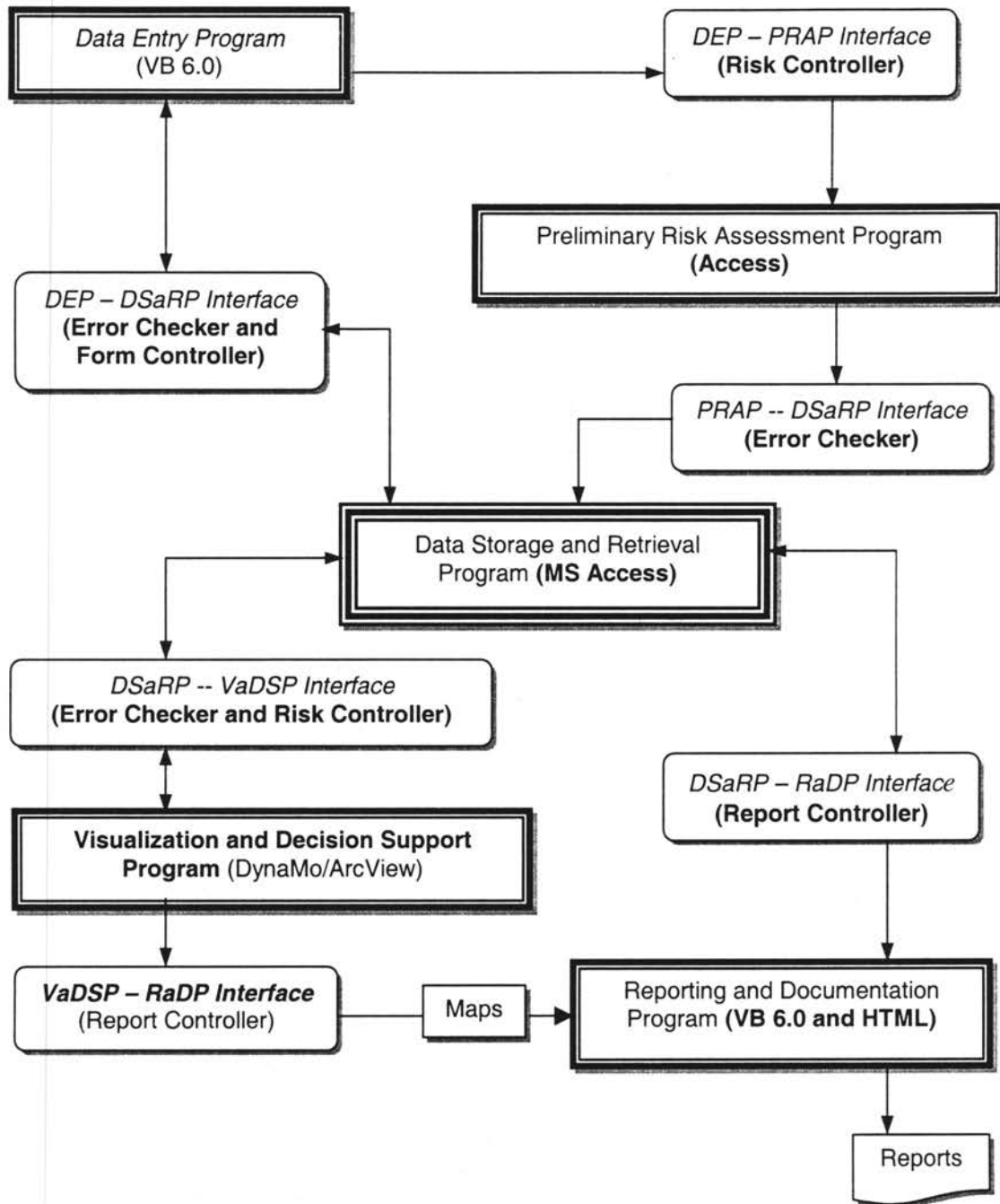


Figure 4-1. EESASS PROGRAM BLOCK DIAGRAM

#### 4.2. Data Entry Program (DEP)

To assist and guide the assessor in data entry, a series of discreet input forms were developed with Visual Basic 6.0<sup>®</sup>. These graphic user interface (GUI) forms prompt the assessor for the information required by EESASS. A module block diagram for DEP is presented below.

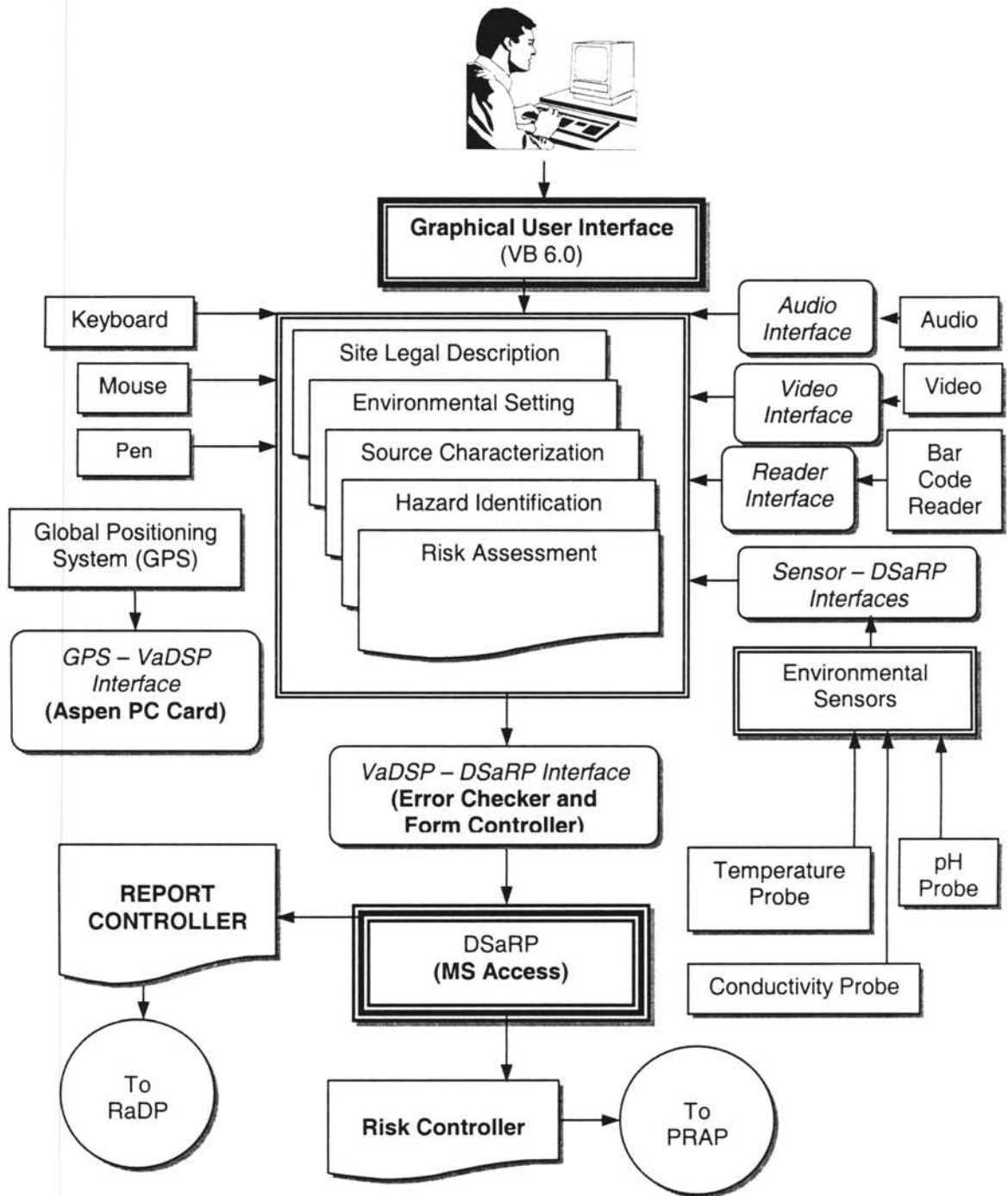


FIGURE 4-2. DEP MODULE BLOCK DIAGRAM



**4.2.1. GUI Form Design:** Graphical user Interfaces (GUIs) have become standard devices for data entry and processing. EESASS adopted GUI as the basis for the design and development of forms to facilitate the entry of environmental site assessment data into the EESASS database and for risk calculations, GIS displays, decision support, and reporting. Input forms were developed using Visual Basic 6.0<sup>®</sup> and were made compatible with other program components. The forms were organized into seven sets, or modules.

- ◆ Legal Information
- ◆ Environmental Setting
- ◆ Source Characterization
- ◆ Hazard Identification
- ◆ Risk Assessment
- ◆ Decision Support
- ◆ Report Controller

**4.2.2. Data Entry:** Data entry into the GUI input forms can be accomplished by keyboard, pen, mouse, and PCMCIA card (the card is used for entry of GPS data, environmental sensor measurements, bar code scanner data, video images, and audio clips). Wherever feasible, formatting and other explanatory information were included in context-sensitive help features associated with the GUI forms. For numerical inputs, default values are often displayed in the corresponding fields or in context-sensitive help messages. However, the assessor can override all default values. Acceptable input value ranges are also provided, where appropriate. An error-checking module checks for proper formatting and value ranges before data is accepted into the database. Rejected data, with an explanatory error message, will be reported to the assessor via the input form.

Three types of fields are specified in the GUI forms. Super-mandatory fields (indicated by the presence of two asterisks before the field label) require data input before EESASS will allow the assessor to proceed with the assessment. Mandatory fields are accompanied by one asterisk before the field label. These fields require legal data entry before the form is considered

complete. An empty mandatory field will trigger an error message in the GUI form. After inputting the data, the assessor can proceed to the next form. Non-mandatory (optional) fields have no asterisks displayed before the field label. Most fields in the input forms are optional. The assessor can choose to provide input or to ignore these fields as he or she chooses.

4.2.3. **Form Controller Module:** EESASS includes a form controller module built within its database. This module calls forms in a pre-defined sequence depending on responses provided in earlier forms. The use of a form controller module relieves the assessor from having to know which forms are required when. The assessor simply enters data prompted by forms and can be assured that all data necessary to complete an ASTM-compliant environmental site assessment have been obtained. It is highly unlikely that all forms will be required by any one assessment.

The form controller tracks both those forms that have been completed and those that have been confirmed for accuracy. Completed forms are those in which all super-mandatory and mandatory fields have had legal data entered. Any form (except the two super mandatory field forms) can be left incomplete during any particular input session and completed later. Confirmation is an assessor-controlled input that indicates that the information contained in the form has been validated as accurate. The assessor cannot verify an incomplete form.

The completeness and confirmation status of all forms required during a particular site assessment are displayed in a hierarchical tree structure, similar to Microsoft's Windows Explorer<sup>®</sup>. The tree structure allows the assessor to call any form in any order, independently of the form controller. This will allow the assessor to complete, confirm, or review any form at any time. This feature accommodates the reality of data acquisition: data is typically gathered by data source location rather than by topic. In addition, all of the data necessary to complete a form is often not available the first time a form is called and data entered into it. As a result, a form may be called several times before it is completed and marked confirmed. The tree structure facilitates out-of-order (non-controller-sequenced) form calls, which improves the speed and convenience of data entry.

### 4.3. Data Storage and Retrieval Program (DSaRP)

In EESASS, all data are stored and managed by a relational database built with Microsoft Access 97<sup>®</sup>. The database consists of two types of databases: fixed and variable input. Those are described in the followings.

**4.3.1. Fixed Databases:** Three fixed databases were constructed and populated under EESASS. These will not be available for modification by the assessor.

**4.3.1.1. Soil Texture Database:** Soil texture information is included for four soil textures: Gravel, Sand, Silt, and Clay. The soil texture appropriate to given site location must be input by the assessor from a list box. The assessor is permitted to input only one soil texture for the entire site; therefore, only the dominant soil texture should be used.<sup>3</sup> For each soil texture, the following soil and aquifer hydrologic information are stored in the soil texture database:

- ◆ Soil organic matter content
- ◆ Average soil porosity
- ◆ Average aquifer permeability
- ◆ Average aquifer thickness
- ◆ Average aquifer Darcian velocity
- ◆ Aquifer storage coefficient

For purposes of screening assessments, the two-dimensional models used to model fate and transport of toxicants through groundwater assume aquifer homogeneity, isotropy, infinite areal extent, and constant head. Unsaturated zone movement modeling also assumes homogeneity and isotropy.

**4.3.1.2. Chemical Property (ChemProp) Database:** The chemical property database includes the following information for each of the IRIS chemicals stored in it.

- ◆ Chemical Abstract System number

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<sup>3</sup> Currently, no plans exist for allowing the input of more than one soil texture on a site. However, in future EESASS revisions, the assessor will be permitted to specify the areal extent of a particular soil texture by inputting polygon coordinates or by drawing areas on a site map with the pen.

- ◆ Common name
- ◆ Atomic or molecular weight
- ◆ Diffusivity of the chemical in air
- ◆ Diffusivity of the chemical in water
- ◆ Water solubility
- ◆ Vapor pressure
- ◆ Henry's law constant
- ◆ Organic matter content

4.3.1.1 *Chemical Toxicity (ChemTox) Database*: Chemical-specific toxicity values have been promulgated by EPA in IRIS for the 450 chemicals included therein. Toxicity values include:

- ◆ Reference doses (oral, inhalation, and dermal) – for systemic toxicants (mg/kg/day) [n=340]
- ◆ Slope factors (oral, inhalation, and dermal) – for carcinogens (mg/kg/d)<sup>-1</sup> [n=180]
- ◆ Class (Weight of Evidence)
- ◆ Permeability Factor
- ◆ Adsorption Factor
- ◆ GI Adsorption Factor

Reference doses specific to sub chronic, acute, and developmental are not included in version 1.0 of EESASS. But response-specific (toxicological parameter-specific or endpoint-specific) values were considered for both reference doses (e.g., Oral RfDs, Inhalation RfDs) and slope factors (e.g., Oral SF, Dermal SF, and Inhalation SF). This conservative approach assumes that multiple systemic or carcinogenic toxicant risks are additive (US EPA 1989a).

**4.3.2. Input Databases:** To accommodate inputs made by the assessor through GUI forms or from calculations made by EESASS programs, the following input databases were created to store environmental site assessment data.

4.3.2.1. *GUI Forms:* Data input by the site assessor via GUI input forms will be stored in GUI form databases. Seven of these are modules are included in EESASS. Those seven modules were already summarized in section 4.2.1.

4.3.2.2. *E-FAST Devices:* Several E-FAST devices were planned, each of which will produce data for input into the EESASS database. These include the following:

- ◆ Environmental sensor data (pH, Temperature, Conductivity, Specific Conductance)
- ◆ Bar code scanner data
- ◆ Digital graphic data (photographs stored as .jpeg files)
- ◆ Moving video data
- ◆ Sound data

Nomadics, Inc. utilized DynaModule<sup>®</sup> to input environmental sensor and barcode scanner data. Those data will be transferred to distinct locations in the EESASS database. Version 1.0 of EESASS does not include that interface to transfer that data. The digital graphic, moving video and sound data are stored in the "Multimedia" table of the EESASS database. The project made several attempts to capture those data and store them in the database. But in each case, the computer froze. Thus, this version of EESASS stored those data in the database table manually.

4.3.2.3. *GPS Data:* GPS spatial and time data will also be input into the EESASS database via GUI control from a PCMCIA-based Aspen Gold Card. Nomadic Inc. employed DynaModule<sup>®</sup> to capture the GPS Input. Data points obtained from the GPS system will be transferred to Microsoft Access<sup>®</sup> through an interface. Input of GPS data will be called by GUI input forms associated with on-site ESA activities.

4.3.2.4. *GIS Themes:* GIS requires both spatial data (stored as ESRI-format shape files) and non-spatial data (stored as text or numerical data). Spatial data are inputted into the database for use by the GIS software from GPS, scanners, or as digital data obtained from electronic storage.

Non-spatial data include attribute data for site, source, release, pathway, receptor, and environmental setting data that are inputted into EESASS database via GUI forms. Those Microsoft Access® data are later converted to Dbase® IV format and transferred to the ArcView® database to create the GIS themes. In addition, chemical concentration and risk estimates are imported to the ArcView® database from the risk calculation database.

*4.3.2.5. Preliminary Risk Assessment:* Data required to run the risk modules are stored in the EESASS database. These data are provided through GUI forms, as discussed above.

*4.3.2.6. Error-Checking:* Data inputs to the EESASS database is checked for proper formats and value before being stored. .

**4.3.3. Output Databases:** Several output databases within EESASS are described next.

*4.3.3.1. Preliminary Risk Assessment Program:* Several risk assessment modules are included in the PRAP, each of which will produce outputs that will be stored in the DSaRP database. One of these modules is the Risk Characterization Module. It contains three processes:

- ◆ Environmental fate and transport calculations
- ◆ Dosimetry
- ◆ Risk estimation

Fate and transport functions will export migration pathway-specific chemical concentrations near a receptor (e.g., mg/liter of water, mg/kg of soil,  $\mu\text{g}/\text{m}^3$  of air) to the database. Dosimetry functions will export chemical-specific, receptor-specific dose estimates (mg of toxicant / kg of body weight / day of exposure) to the appropriate database queries. Receptor-specific, response-specific risk estimates are produced by the risk estimation functions and are exported to the database as dimensionless values. All these three processes were explained in details in PRAP section.

*4.3.3.2. GIS Base and Decision Support Maps (Shape Files):* Spatial data, either input via other input modes or generated by the DynaMo program itself (e.g., via queries) are stored as ESRI-

format shape files in the database and are linked to other site specific attribute tables in the database.

**4.3.3.3. GIS Queries:** Two types of queries are possible in the GIS program. The first of these are database queries in which spatial data is simply recalled and displayed along with attribute tables, features, and text. These queries are routinely stored in an output database. The second of these are decision support queries. These require the execution of modules within the Preliminary Risk Assessment Program and are discussed more fully there. The results of baseline risk assessments are stored in EESASS output databases.

**4.3.3.4. Reports:** Two report formats are generated by EESASS version 1.0. All data required by these reports are stored in report output databases.

**4.3.4. Data Integrity:** Data integrity is assured via error checking. The error checking module checks specified data strings sent to the database for errors. At the time of input, when an error occurs, the module will trigger a message describing the error.

**4.3.5. Error Types:** The Error Checker tracks two types of errors:

- Input Errors
- Calculation Errors

**4.3.5.1. Input Errors:** Adding validation rules into the field specifications in MS Access® can check all Input Errors. The following input errors are defined:

- Format Errors
- Range Errors
- Empty Field Errors (Primary Key)
- Duplicated Field Errors (Primary Key)

When MS Access® finds an error, it sends the appropriate error message to the Error Collection Object and Visual Basic 6.0® will then pop up the corresponding error message.

**4.3.5.2. Calculation Errors:** Since the risk assessment program is so important but yet a complex component of EESASS, it is easily possible to generate values that are not realistic. Error

checking was used to identify such errors by using range checking in each equation and final result.

If a Calculation Error occurs, Error Checking sends the appropriate message to the Risk Controller Module and pop-up an error message to show which step generated the error.

#### **4.4. Preliminary Risk Assessment Program (PRAP)**

One of the most powerful features of EESASS is the automated risk estimation, which aids the site assessor in determining which environmental exposures present unacceptable risks and in prioritizing responses to such risks – each under assessor-specified land use and remediation scenarios. The modeling of exposures and risks are accomplished by adapting the risk-based corrective action protocol defined by ASTM E 1729 and the contaminant transport models included in the APIDSS package. The type of model used depends on the environmental pathway or pathways that the toxicant takes on its way to the receptor. The assessor must first select the pathway(s) through which a toxicant can reach a receptor, then input the initial environmental toxicant concentration at the location removed from the receptor, and finally input the physical and chemical properties of the pathway(s). The output of the calculation is the estimated environmental concentration at the receptor. Since most existing policies require that the most exposed individual (MEI) be protected, normally the concentration produced from this calculation is referred to as the MEI concentration. A block diagram of the PRAP module is shown in the following figure 4-3.

**4.4.1. Organization of PRAP Modules:** The risk models used in PRAP can be organized into three groups: fate and transport models, dosimetric models, and risk characterization models. In PRAP, each of these groups is organized as a module. Several processes are included in each module. Each one representing an individual migration pathway, dose calculation, or risk estimate, respectively. Each module is discussed in the following.



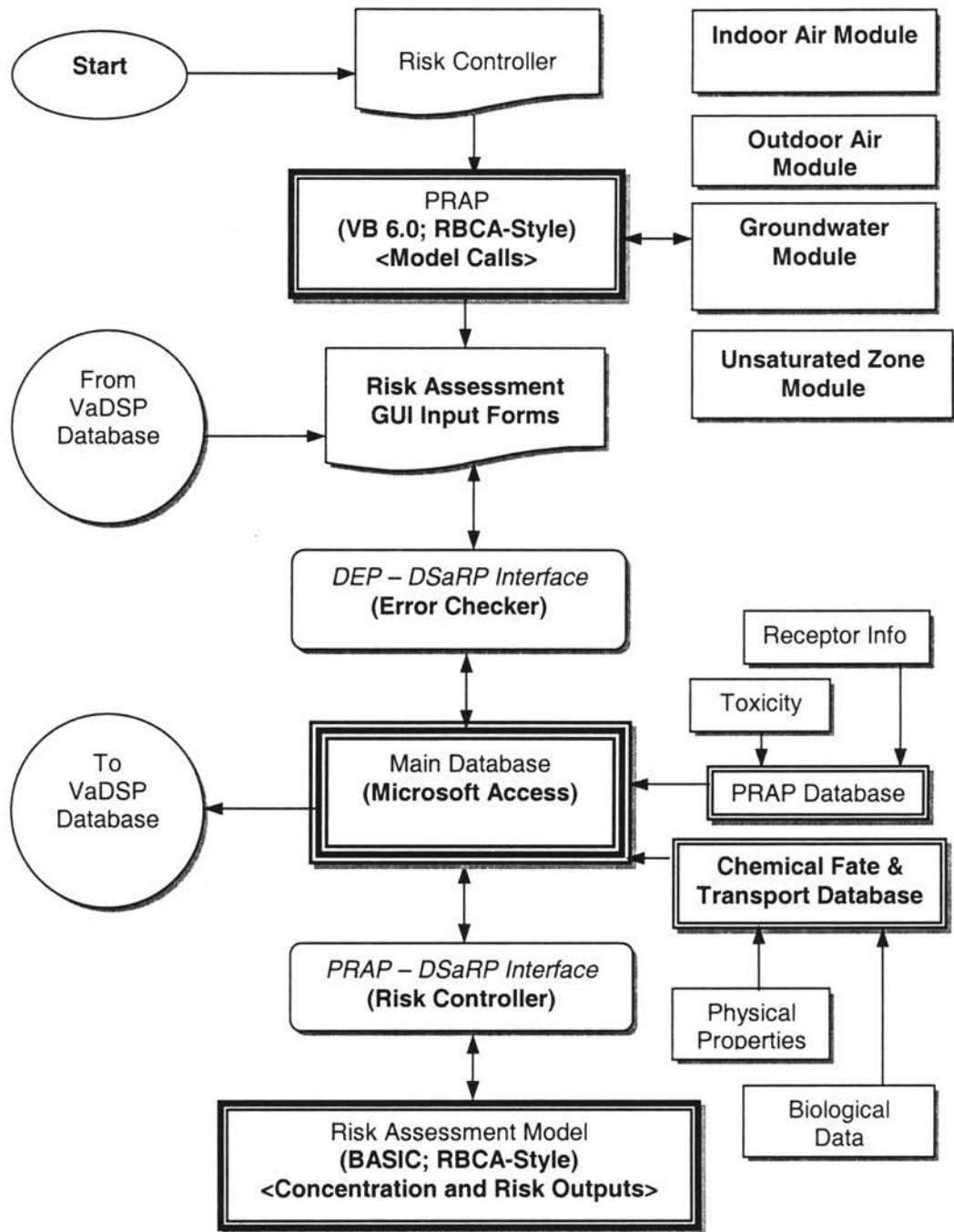


FIGURE 4-3. PRAP MODULE BLOCK DIAGRAM

4.4.1.1. *The Fate and Transport Module:* The fate and transport module contains 17 processes, each of which describes the concentration of a toxicant as it moves through a particular migration

pathway. Fate and transport processes are used to estimate the environmental concentration of a toxicant at a receptor given the concentration at a location removed from the receptor.

4.4.1.1.1 Selection of Initial Concentration: Often, the initial concentration is the area of contamination. However, any point from then source to anywhere along the pathway can be used. The following options are available in PRAP:

- Initial point is the area of contamination. This is commonly the case. The area of contamination (AOC) is usually located at or near the source unit.
- Initial concentration is the source. When it is infeasible to sample the AOC and if it is reasonable to expect that the AOC would contain toxicant concentrations similar to those found in the source unit, the source concentration may be used.
- Initial concentration is along a migration pathway between the AOC and the receptor. This would be the case, for example, if a ground water quality measurement is taken from a monitoring well located down gradient of the AOC.
- Initial concentration is taken at the receptor's location. In this case, there is no reason to use a fate and transport model; the MEI concentration is measured directly.

4.4.1.1.2. Selection of MEI Receptor: The choice of MEI receptor depends on the particular combination of hazard elements that connects the receptor with the source or AOC. Each distinct combination is a different hazard and therefore must be treated separately by PRAP. Often, there are several MEI receptors at or near a site that must be addressed in a site assessment. For example, different MEIs could be chosen for a hazard linking toxicant A moving from source 1 through the groundwater pathway and entering an MEI via oral ingestion of drinking water compared to a hazard linking toxicant B moving from source 2 through the air pathway and entering another MEI through inhalation. Unless groundwater flow coincided with the predominant wind direction and the MEI was breathing outdoor air much of the time and was frequently drinking contaminated groundwater at the same location as well, two MEIs will probably be identified.

4.4.1.1.3. Selection of Relevant Migration Pathways: The selection of relevant environmental pathways along which toxicants can migrate to exposed receptors requires expertise. In part, the choices depend on the physical characteristics of the toxicant (e.g., volatility at standard pressures and temperatures); the physical characteristics of the environmental media pathways (e.g., presence of impermeable geological strata that prevent the vertical migration of leachate from the source to groundwater); the location, duration, and amount of the release (e.g., large spills to surface soil that are allowed to remain in the environment for long periods could move by many more pathways than a small spill contained in a lined dike system surrounding a tank); and the location and behavioral habits of potential receptors (e.g., whether children swim in the nearby stream or whether people enter the site through a damaged fence or unlocked gate, etc.); climatological and other site physiographic characteristics (e.g., volatilization is minimal during cold and wet weather, surface runoff is less a problem in an arid climate); and whether there are intermedia or interpathway connections (e.g., from groundwater to air or from soil to air).

4.4.1.1.4. Selection of Process: The fate and transport process that is run depends primarily on the answers to the previous questions. However, the user is free to select any process he or she desires.

4.4.1.1.5. Input of Parameter Values: For most parameters, default values are provided. Wherever possible, acceptable ranges of values (e.g. the acceptable range of value for pH is 1-14) were stored and checked. Despite these features, however, some parameters will have to be input by the assessor. Units for all inputs were provided on the GUI input forms. The parameters required depend on the migration pathways selected.

4.4.1.1.6. Fate and Transport Processes: The combination of pathways of migration for the toxicants, initial concentration, type of exposure (Proximal and Distal), and the intake route (inhalation, oral ingestion and dermal contact) yield 41 pairs. Those are represented in the following table. Thus, PRAP included options only for four single media migrations and eight cross-media migrations.

Primary Medium	Conc. Known	Second Medium	Conc. Known	Third Medium	Conc. Known	Terminal Medium	Exposure Type	Intake Route
Air	Yes					Air	Proximal	Inhalation
Air	Yes					Air	Distal	Inhalation
AOC	Yes					AOC	Proximal	Dermal
AOC	Yes					AOC	Proximal	Ingestion
AOC	Yes	Air	No			Air	Ambient	Inhalation
AOC	Yes	Air	Yes			Air	Ambient	Inhalation
AOC	Yes	Air	No			Air	Indoor	Inhalation
AOC	Yes	Air	Yes			Air	Indoor	Inhalation
AOC	Yes	Air	No			Air	Distal	Inhalation
AOC	Yes	Air	Yes			Air	Distal	Inhalation
AOC	Yes	GW	No			GW	Proximal	Ingestion
AOC	Yes	GW	Yes			GW	Proximal	Ingestion
AOC	Yes	GW	No			GW	Proximal	Dermal_Shower
AOC	Yes	GW	Yes			GW	Proximal	Dermal_Shower
AOC	Yes	GW	No			GW	Distal	Ingestion
AOC	Yes	GW	Yes			GW	Distal	Ingestion
AOC	Yes	GW	No			GW	Distal	Dermal-Shower
AOC	Yes	GW	Yes			GW	Distal	Dermal-Shower
AOC	Yes	GW	No	Air	No	Air	Proximal	Inhalation
AOC	Yes	GW	Yes	Air	No	Air	Proximal	Inhalation
AOC	Yes	GW	Yes	Air	Yes	Air	Proximal	Inhalation
AOC	Yes	GW	No	Air	No	Air	Indoor	Inhalation
AOC	Yes	GW	Yes	Air	No	Air	Indoor	Inhalation
AOC	Yes	GW	Yes	Air	Yes	Air	Indoor	Inhalation
AOC	Yes	GW	No	Air	No	Air	Distal	Inhalation
AOC	Yes	GW	Yes	Air	No	Air	Distal	Inhalation
AOC	Yes	GW	Yes	Air	Yes	Air	Distal	Inhalation
SW	Yes					SW	Proximal	Ingestion
SW	Yes					SW	Proximal	Dermal-Shower
SW	Yes					SW	Distal	Ingestion
SW	Yes					SW	Distal	Dermal-Shower
GW	Yes					GW	Proximal	Ingestion
GW	Yes					GW	Proximal	Dermal-Shower
GW	Yes					GW	Distal	Ingestion
GW	Yes					GW	Distal	Dermal-Shower
GW	Yes	Air	No			Air	Ambient	Inhalation
GW	Yes	Air	Yes			Air	Ambient	Inhalation
GW	Yes	Air	No			Air	Indoor	Inhalation
GW	Yes	Air	Yes			Air	Indoor	Inhalation
GW	Yes	Air	No			Air	Distal	Inhalation
GW	Yes	Air	Yes			Air	Distal	Inhalation

Table 4-1. PRAP Fate and Transport Processes

◆ **Physical Forms of the Toxicant**

- Vapors, and Gases
- Miscible / Immiscible Liquids (DNAPLs and LNAPLs)
- Solids

◆ **Migration Pathway**

- Vadose Zone (Unsaturated Zone)
- Surficial Soil
- Subsurface Soil
- Indoor Air
- Proximal Ambient Air
- Distal Ambient Air
- Groundwater
- Distal Groundwater
- Surface Water

4.4.1.2. *The Dosimetry Module:* The second group of processes are the dose equations that convert MEI toxicant concentration to dose (mg of toxicant per kg of body weight per day of exposure). There are several parameters that serve as inputs into dose equations. As mentioned already in section 4.4.3.1.1.1, MEI environmental toxicant concentration is one of these. Other parameters include physical and behavioral characteristics of the receptor and biochemical properties of the toxicant.

4.4.1.2.1. Parameters Relating to the Receptor

◆ **Intake Routes**

The assessor must first specify the routes of entry into the body that a toxicant can take. These choices depend on the migration pathways by which the toxicant moved to the receptor and on the behavior of the receptor. Possible intake routes include:

- oral ingestion of liquids (usually water)
- oral ingestion of soil

- inhalation of air
- dermal absorption of liquids

Food ingestion is not considered in PRAP.

#### ◆ **Intake Rates**

For each of the intake routes, there is a corresponding intake rate. Rates represent the mass of toxicant entering the receptor's body per unit time. Units of intake rate vary with the intake route:

- liters of liquid ingested per day of exposure (oral ingestion of liquids)
- mg of soil ingested per day of exposure (oral ingestion of soil)
- cubic meters of air inhaled per day of exposure (pulmonary inhalation)
- mg of liquid absorbed through the skin per square centimeter of exposed skin area per day of exposure (dermal absorption)

Default values are included in PRAP for each of these rates.

#### ◆ **Body Weight**

A fundamental principle of toxicology is that adverse response to toxicants is proportional to concentration in the body (referred to as dose) rather than quantity or mass. In effect, the toxicant is diluted by the body and this dilution must be taken into account in risk equations.

Default values are included based on gender and age.

#### ◆ **Exposure Time**

The time over which a receptor is exposed to a toxicant is, of course, directly related to the dose.

Exposure time is calculated as the product of three factors:

Exposure period (years) x Exposure frequency (days/year) x Exposure duration (hours/day)

The exposure time is then divided by the averaging time (the period of time that exposure is assumed to occur in developing toxicity values). Averaging time = 70 years (equivalent to lifetime) for carcinogens. Averaging time varies for systemic toxicant exposures, depending on land use assumptions. For example, AT = 40 years for residential exposure and 30 years for

occupational exposure. These values are stored as defaults in the dose processes; however, the assessor can elect to override the defaults and enter more realistic data if he or she so chooses.

#### 4.4.1.2.2. Parameters Relating to the Toxicant

- ◆ Chemical Type (carcinogen, systemic toxicant)
  - Absorption Coefficient
  - Chemical Concentration

4.4.1.3. *Risk Characterization Module:* The third level equations are the risk equations. These equations used the MEI dose and estimated the risk to which the MEI is exposed. MEI risk can also be estimated directly from the from MEI concentration without calculating dose – if the assumptions about receptor intake, absorption coefficients, body weight, and exposure time are valid.

- ◆ **Carcinogens**
  - Risk = (Slope Factor)(MEI Dose)
  - Cumulative Risk =  $\Sigma$  Risks
- ◆ **Systemic Toxicants**
  - Hazard Quotient = [(MEI Concentration) / (RfC)]
  - Hazard Quotient = [(MEI Dose) / (RfD)]
  - Hazard Index =  $\Sigma$  Hazard Quotients

4.4.2. **Data Handling:** Data obtained during the pre-site visit activities and the on-site visit are combined with built-in defaults stored in the EESASS databases to be fed into contaminant transport models to estimate exposure concentrations at actual or potential receptors. These estimated environmental concentrations combine receptor demographic and behavioral characteristics to calculate doses. The doses are combined with toxicity data (dose-response values) to estimate both carcinogenic and systemic toxic responses in exposed receptors. Both individual and cumulative risks are calculated, for both systemic and carcinogenic risks. These risk estimates are graphically displayed on maps so that the site assessor can see where unacceptable risks exist under current land use conditions, as well as to identify which risks are of

most concern, which are of lesser but still significant concern, and which are of little or no concern. This capability also assists the assessor in determining various site remediation strategies to reduce the unacceptable risk to acceptable ones.

**4.4.3. Identification of Default Values and Acceptable Ranges:** Fate and transport equations include many variables pertaining to the physical or chemical characteristics of the environmental medium (e.g., organic matter content in soil, air temperature, wind velocity, moisture content). These equations also include variables pertaining to the toxicant (e.g., concentration, vapor pressure, solubility, density). Since EESASS incorporates a conservative approach to preliminary (screening) risk assessment, it develops default values and/or acceptable ranges for most of these parameters. These values and ranges are incorporated into these modules. As mentioned earlier, an error-checking module is incorporated into EESASS to prevent invalid inputs to the database.

#### **4.5. Visualization and Decision Support Program (VaDSP)**

Geographic information system (GIS) capability adds a powerful dimension to the decision support function of EESASS. Given GIS's capability of displaying spatial data as points, lines, or polygons arranged in single or multiple overlapping themes or coverages, underlain by complex databases, and capable of executing complex queries and displaying the results of these queries on a map, makes GIS an essential component of EESASS. In fact, the GIS will function as the primary assessor interface during decision support. VaDSP used DynaMo<sup>®</sup> as its GIS package. DynaMo<sup>®</sup> was chosen because it is fully compatible with ArcInfo and ArcView, it readily accepts GPS input via a PCMCIA card, it allows limited programming through the use of DynaModules, and it does not require exorbitant resources to run. A block diagram of VaDSP module is shown in figure 4-4.



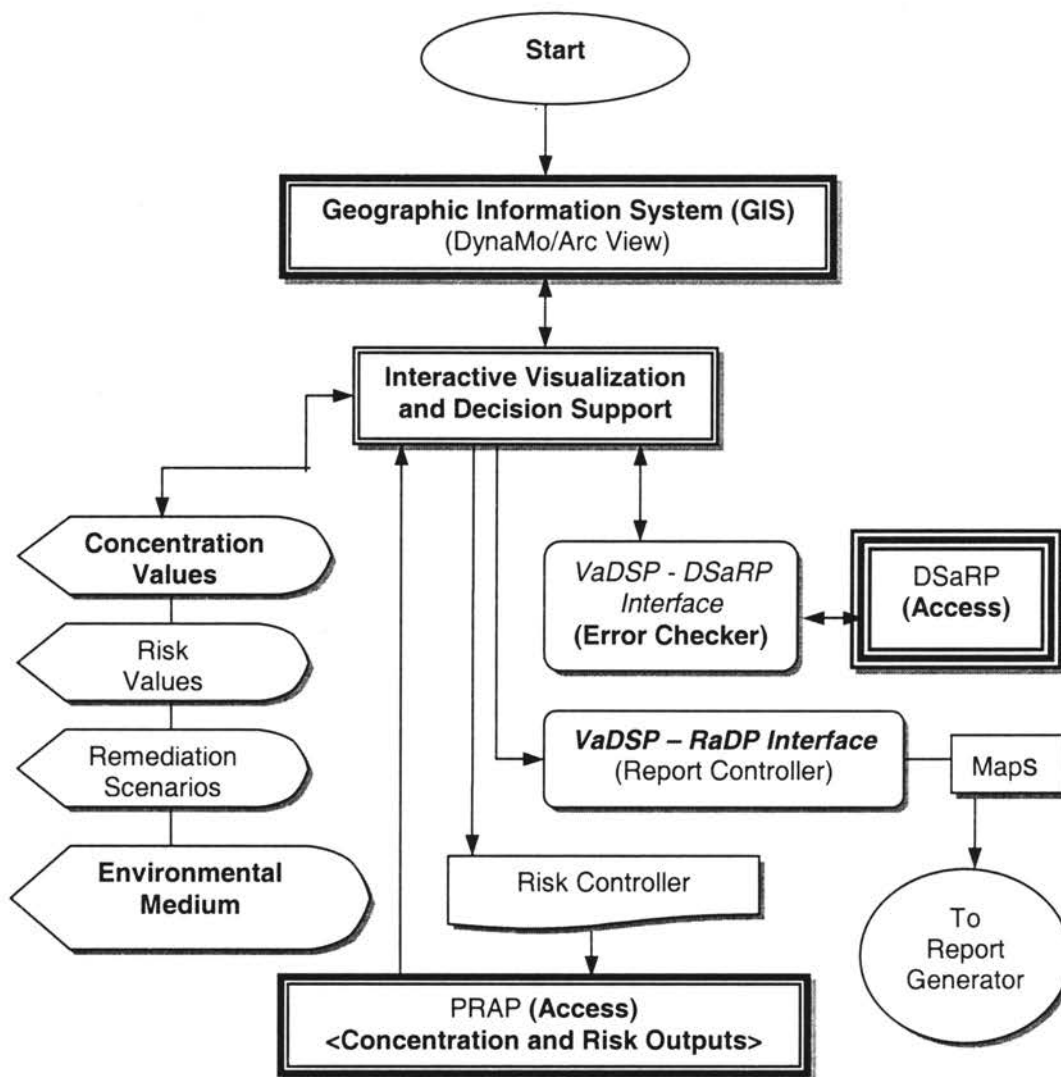


FIGURE 4-4 VADSP MODULE BLOCK DIAGRAM

**4.5.1. Functional Specification of GIS:** EESASS utilizes ArcView 3.1<sup>®</sup> geographical information system (GIS) software to generate physical, environmental, and risk coverage. There are eight physical and environmental coverages in ArcView. The information underlying each of the coverages is discussed in the following.

Each class of environmental exposure pathways is represented in GIS as a data layer or coverage. The coverages can be scanned into ArcView<sup>®</sup> that contain information about environmental media through which toxicants can move from sources of release to receptors:

groundwater, surface water, and surficial soil. On each coverage, individual pathways will be identified, e.g., the uppermost aquifer, streams, and soil texture, respectively. (Air pathways will not be shown as a distinct coverage area. Instead, wind rose data is displayed as tabular attribute data.)

Overlaying each pathway are source and receptor data layers. Any particular source can be linked to any area of contamination, thence to any pathway, thence to any intake route, and hence to any receptor, as appropriate. Of course, not all sources, areas, pathways, intakes and receptors need be linked to areas of contamination pathways and not all pathways need to be linked to each other. Links must be established using the inputting data in the release form.

The hazard, toxicant concentration, and risk attributes by source, area of contamination, pathway(s), intake route, and receptor which can be revealed simply by importing risk information table from EESASS database. The toxicant concentration map displays environmental concentrations of toxicants at the sampling points (usually at current or future receptor locations). The concentrations can be measured or (given appropriate input parameters) modeled within the PRAP component of EESASS. In addition, risk estimates can also be displayed at the same locations as toxicant concentrations. The visualization of toxicant concentrations and their concomitant risk estimates is straightforward. In EESASS, where two risk displays will be used: carcinogenic risk and non-carcinogenic (or systemic) risk. For carcinogenic risk, if the assessor wants to see which *de manifestis* cumulative risks are posed to receptors, the query result shows such receptors as colored with red. Receptors having *de minimis* risks are displayed as green. Yellow color will mark receptors, who are exposed to risk lying between *de manifestis* and *de minimis*. For systemic risk, receptors are displayed as green, yellow and red if the corresponding cumulative risks are less than 1, equal to 1 and greater than 1 respectively.

One of the most important features of EESASS is its capability to identify the most important areas of concern for unacceptable risk. For each type of risk (cancer or systemic risk), six pie charts are created within ArcView<sup>®</sup> to assist the assessor in determining these areas of concern. The charts include

- Risk by Intake Route (to determine which intake route(s) is/are critical)
- Risk by Intake Route by Chemical (to determine which chemical(s) is/are mostly responsible for such concern)
- Risk By Medium
- Risk by Medium by Chemical
- Risk by Source
- Risk by Source by Chemical

A customized menu and tool bar have been added to the ArcView<sup>®</sup> interface to make it easier to display coverages and conduct queries. ArcView<sup>®</sup> is also used to display the results of the decision support component of EESASS. The designs of the Menu bar and Toolbar are summarized below.

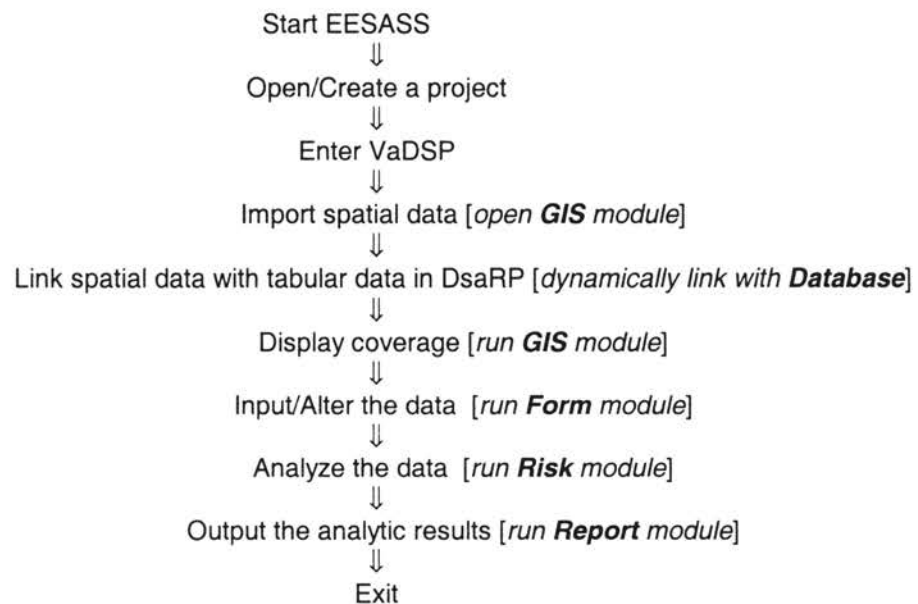
◆ Menu Bar: In addition to normal items, four additional items - Coverage, Toxicant Concentration, Baseline Risk, and Residual Risk are included in the menu bar of the EESASS Arcview<sup>®</sup> Screen. The categories and choices for each item are shown below.

- Coverage
  - Category: Ground Water
    - Choices : Unconfined Aquifer, Confined Aquifer, Drinking Water Wells
  - Category : Surface Water
    - Choices : Offsite SW Body, Onsite SW Body
  - Category: Soil
  - Category: Vegetative Cover
- Toxicant Concentration
  - Category: Sample Points
- Baseline Risk
  - Category: By Intake Route, By Intake Route by Chemical, By Medium, By Medium by Chemical, By Source, By Source by Chemical.

- Residual Risk
  - Category: Equal Reduction
    - Choices: Source, Pathway/Environmental Medium, Intake Route
  - Category: Weighted Average
    - Choices: Source, Pathway/Environmental Medium, Intake Route
  - Category: Worst Case
    - Choices: Source, Pathway/Environmental Medium, Intake Route
  - Category: Specified Reduction
    - Choices: Source, Pathway/Environmental Medium, Intake Route

◆ Tool Bar: In EESASS, several additional buttons are included in the tool bar for adding or deleting themes. The buttons are supposed to toggle enhanced to add themes of the button choice selected or delete themes of the button choice if themes of that choice are already in the view. This version of EESASS does not include the toggle characteristics of the buttons. The Add/Delete themes buttons are: Base Map, Ground Water, Surface Water, Soil, Vegetative Cover, Air, Receptor, Release, Total Cancer Risk, Total Systemic Risk and Create Map.

**4.5.2. VaDSP Structure:** The structure of the interface between VaDSP and DSaRP is partially determined by the assessor. A typical sequence of activities is described by the following.



Five modules are defined within VaDSP. They are *GIS, Database, Form, Risk, and Report*.

#### **4.6. Reporting and Documentation Program (RaDP)**

Another powerful feature of EESASS is its ability to provide multi-media electronic reports. EESASS can generate reports for three phases of the assessments. The reports are preformatted to ensure that they fully comply with ASTM environmental site assessment reporting requirement and are of consistent quality. They are also flexible enough to seamlessly accommodate site-specific information and allow several options for information presentation and document inclusion. Each report was so well organized, richly informative that they foster understanding of the environmental risks present at the site and to facilitate decision-making concerning risk mitigation.

Version 1.0 of EESASS can generate two types of reports for each assessment - text only, and text with graphics using Microsoft Visual Basic 6.0<sup>®</sup> and Hypertext Markup Language<sup>®</sup> (HTML). The main body of each report is similar in organization and style. The chief difference among the two is the inclusion or exclusion of multimedia images and sound clips. In text with graphics report, links are be provided in the report document to GIS map queries, analytical results, video clips, and other text information. The module block diagram for this program is presented in figure 4-5.

**4.6.1. Report Appendices:** These appendices can be as short or as long as the assessor wishes and resources allow. Two types of material are included in the appendices: maps generated from the geographic information system included within EESASS and tables generated by the database program within EESASS.

**4.6.1.1. GIS Maps:** Several themes or coverages are available for display and output from the GIS program within EESASS. The assessor is accorded considerable flexibility in choosing what and how to display and output themes, data within themes, and query results in electronic and paper reports.

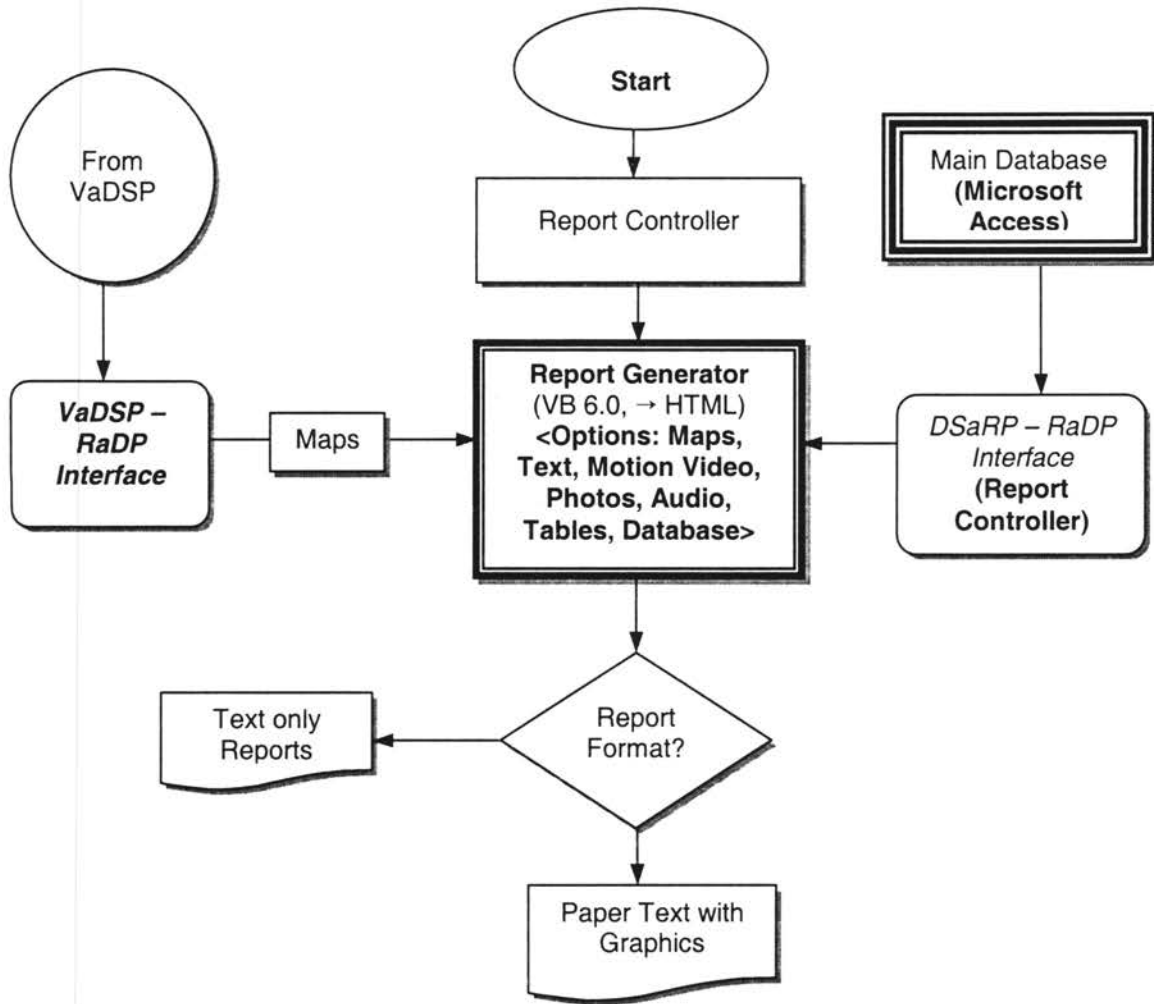


Figure 4-5. RaDP Module Block Diagram

4.6.1.1.1. Baseline Site Map: The baseline site map includes those facility, environmental setting, land use, source, and release themes that the assessor desires to include in a report. The default set will include the facility drawing, source, release, surface water, wind rose, and land use schemes. Other themes available for substitution or addition include groundwater potentiometric surface, soil texture, topographic surface, and vegetation themes. The purpose of this map is to illustrate the current physical layout of the facility and relevant environmental and land use settings on which site assessment and decision support information will later be presented and analyzed.

4.6.1.1.2. Baseline Receptor Map: The map represents the most exposed receptors present at the site. The cumulative cancer and systemic risks are calculated for those receptors.

4.6.1.1.3. Baseline Concentration Map: Three types of chemical-specific and environmental medium-specific ambient toxicant concentrations can be displayed on the baseline concentration map: source/release concentrations, pathway concentrations, and receptor concentrations. The first two of these are usually measured and input into the database via GUI input forms. The third is usually calculated from the fate and transport models included in the preliminary risk assessment program of EESASS. Concentrations are expressed as milligrams per liter (water), milligrams per kilogram (soil), and micrograms per cubic meter (air).

4.6.1.1.4. Baseline Risk Maps (Cancer and Systemic Risk): Baseline risks are those risks posed to the maximum exposed human receptors by environmental toxicants at a site before any site remediation (risk management) is conducted. Thus, these estimates represent the level of risk that exists to the receptor under current exposure conditions.

Cumulative risks for each MEI are displayed as a default display. Cumulative risk includes the sum of four components of risk: (1) exposure to multiple toxicants; (2) migrating from multiple sources and releases; (3) through multiple environmental pathways; and (4) into the body of the receptor by multiple intake routes. Since cancer and systemic risks cannot be summed and therefore they are displayed separately. The default cumulative risk display shows all combination of sources/releases, pathways, and intakes for any one receptor.

4.6.1.1.4.1. Preliminary Cancer Risk Assessment: Cumulative cancer risks (probabilities) are displayed in a table next to the MEI receptor as exponentials (e.g., 4.5E-6). All risk estimates above the *de manifestis* risk level of 1.0E-4 will be shown in red. Risk estimates below the *de minimis* level of 10E-6 will be shown in green. Risk estimates between *de minimis* and *de manifestis* will be shown in yellow.

Individual cancer risks are displayed in a table next to MEI receptor, which is followed by the name of the chemical, followed by the source/release identifier, followed by the identifier of the terminal pathway, and followed by intake route. The risks will be ranked in descending order. Cumulative risks will be computed as sums arranged by chemical, by source/release, by pathway, by intake, and by pathway-intake combination.

4.6.1.1.4.2. Preliminary Systemic Risk Assessment: Systemic risk data will be displayed in the same manner as will cancer risk estimates except that the exponentials represent severity-related hazard quotients/indexes rather than probabilities.

4.6.1.1.5. Decision Support Maps: Though the baseline risk maps can serve a decision support function, they can do so only for prioritization of risk assessments based on a preliminary risk screening. By looking at various sources, releases, pathways, and receptor intervention strategies, the site assessor can explore the impact of decisions that go beyond risk assessment and enter the realm of risk management. In other words, the changes in risk estimates that result from the remediation of sources and releases, interruptions of pathways of migration, and modifications to receptor behaviors and locations can reduce risks in various ways and by varying amounts. By exploring the impacts of various remediation strategies, the assessor can better identify where interim remedial measures can best be taken to reduce risk most effectively and efficiently and thus buy time for more careful study later.

Version 1.0 of EESASS includes twelve different risk reduction strategies through which the assessor can reduce the unacceptable risk to acceptable risk. Thus, the decision support module will usually require multiple runs. Each run represents a changed risk management scenario. After each run, the assessor will be prompted to save the run and associated map.



## **CHAPTER 5**

### **SUMMARY AND CONCLUSION**

#### **5.1. Introduction**

Environmental site assessments have become an important part of routine government operations and private sector transaction. Several guidance documents on the performance of the environmental site assessments have been published to date (e.g. Mikeska and Baldwin 1989; Marburg and Parkin 1991; NGWA 1992; ATSDR 1994; Cahill and Kane 1994; and Sara 1994). There have also been several organizations founded which claim to certify environmental site assessors and auditors. Given the plethora of self-claimed authorities on site assessments, and the wide range of quality of assessments and competencies of assessors, recent efforts at standardizing domestic site assessments have been made. Foremost among these are the standards issued by the American Society for Testing and Materials (ASTM 1993a, 1993b, 1994, 1995, 1997). It is very difficult to perform environmental site assessment using ASTM standards. They are not comprehensive, detail, and organized enough to perform environmental site assessment in an efficient manner. Thus, those problems in ASTM standards need to be solved and some more information need to be added in ASTM standard in order to properly define the conditions of the property or site. Because of all of these reasons, environmental site assessment as it has been practiced to date, has been of variable consistency and dubious quality. The lack of consistency is due, in part, to the lack of a well-defined ESA protocol. The low quality is due, in part, to the failure to incorporate sufficient site-specific data into environmental risk calculations. Thus, it is very difficult to reach a justifiable conclusion regarding hazards at the site.

In addition to standardized ESA protocol, several problems are also associated with the environmental site assessment processes. Manual traditional method (that is guided by a

checklist) is time-consuming, less user-friendly, and has lack of consistency. To solve these problems, attempts have been made to automate the environmental site assessment process. As a part of these efforts, several automated Phase I and Phase II ESA software systems were developed. But no software is available in the market to perform both Phase I and Phase II ESAs. Therefore, the data collected during Phase I investigations must be re-entered for Phase II assessments. Besides, since the designs of all those software systems are based on the different standards and guidance documents, they inherited the same types of problems as those standards. One of the objectives of this research is to develop a standard environmental site assessment protocol, which will resolve the problems in ASTM standards and contain enough information so that the assessor can accurately, effectively and efficiently determine the condition of the property. This project developed a standardized enhanced environmental site assessment protocol. The EESASS Protocol addresses the quality assurance and decision support issues associated with the conduct of an environmental site assessment and the interpretation of the results obtained from there. It adopted two ASTM standards: E-1527 for Phase I Environmental Site Assessments and E-1739 for Risk-Based Corrective Action as a basis for the design of the protocol. However, EESASS protocol goes beyond those standards by incorporating other ASTM and non-ASTM site assessment standards, guidance documents, publications, and lessons learned by site assessors. This foundation assures the assessor that the site assessment will meet or exceed federal and state regulatory requirements for the conduct of environmental site assessments and thus will be acceptable to environmental agencies. The ultimate goal of this project was to automate the enhanced environmental site assessment protocol. An automated enhanced environmental site assessment protocol, "EESASS" have developed in this project. EESASS consists of 1054 graphical-user-input forms with real time data-entry through pen, keyboard, audio, video, GPS and camera. This multi-media forms based system works in conjunction with GIS to provide the user with a portable, powerful, user-friendly environmental assessment decision tool that will not only allow site specific flexibility while maintaining comprehensibility but also will enhance the legal sufficiency of the site assessment data. At the end of inputting the data, the software is able to generate two different types of reports - a plain

text report or text report with embedded sound and video images with links to geographic information systems (GIS) maps.

In addition, EESASS includes a decision support system by incorporating multimedia, graphics-based, visualization tool to an easy-to-use risk assessment model so that it can be used to explore options for further investigation, remediation, and land use changes. The incorporation of Tier I RBCA risk-based screening levels and Tier II site-specific target level calculations, global positioning system, and geographic information system components convert a static report of baseline conditions to an interactive decision support tool.

## **5.2. Problems Associated with EESASS**

The research experienced several problems associated with EESASS.

- (1) **Design of the Multimedia Features:** There is a persistent compatibility problem between Visual Basic 6.0<sup>®</sup> and the Kodak camera (the camera was used to capture video and audio) system card. When we tried to run the video and audio files, the computer froze. Therefore, this version of EESASS does not include audio and video features. Instead, this version of EESASS utilizes scanned images that are manually stored in the multimedia tables of the Microsoft Access<sup>®</sup> database and displays those in the report.
- (2) **Design of the Interface between the Sensors and the Database:** DynaModules<sup>®</sup> are used to input GPS data, sensors data, and barcode reader data. An interface is required to transfer these data into the corresponding attributes database tables located in the Microsoft Access<sup>®</sup> database. No interface was created in this project. As a result, the assessor needs to input those data manually into the GUI forms in this version of EESASS instead of transferring data from DynaModules<sup>®</sup>.
- (3) **Design of the Interface between Report Generator and ArcView:** As mentioned earlier, ArcView<sup>®</sup> is used to generate physical, environmental, and risk coverages. These coverages are presented as appendices in the reports. In electronic version of the report, an interface between report generator and ArcView has to be created to display those coverages automatically. No such interface has been created yet. Therefore, those

maps are included into the multimedia table of the EESASS database manually for displaying them as part of the report.

(4) **Problems with the Report Generator:** The EESASS protocol design includes five electronic and three paper options of report styles. Because of the compatibility problem between the camera and Visual Basic<sup>®</sup>, and due to the absence of the report-GIS interface, version 1.0 of EESASS can produce only two types of reports: text only, and text with graphics. In addition, since the reports are generated in HTML<sup>®</sup> format, they will have formatting problems due to the absence of page breaks. The assessor can, however, import those reports into other word processing programs and edit them there. He/she can include any other features if he/she thinks are important for the assessment.

(5) **Preliminary Risk Assessment Program:** EESASS is designed to perform only human health risk assessment. No ecological receptor being considered during the assessment. This version of EESASS does not include sediment and food as environmental media. In addition, several intermedia transfers are not included as follows.

- Surface water to air
- Air to surface water
- Soil to surface water
- Surface water to soil
- Groundwater to surface water

Chemical transports that not included are:

- DNAPLs in groundwater
- DNAPLs in surface water
- LNAPLs in surface water
- Particulates in air

Finally, one intra-medium that is not included in this version of EESASS is surface water to distal surface water.

- (6) **Size of the Access Database:** The size of the EESASS database is about 26 MB, near the maximum storage capacity for each database under MS Access©. Therefore, relationships among tables could not be established through the Access module. Relationships are an essential element of databases. To work around the problem, relationships were created through modification of the design of the GUI forms. For example, the assessor must re-enter the "Release ID" in every new form of the Hazard Identification section, even it is for the same release. In addition, the increased size of the database reduces the processing speed for saving input data.
- (7) **Soil Properties Table:** In EESASS, the assessor can input only the predominant soil texture type located at the site. No plans exist for allowing the input of more than one soil texture on a site.
- (8) **Wind Rose and Precipitation and Evapotranspiration (PET) Database:** This version of EESASS does not include either database. The assessor must therefore collect this information from other sources and enter it into the GUI forms (instead of gathering them from stored EESASS databases).

### 5.3 Future Improvements

- (1) **Modification of the Database:** Several deficiencies of the design of this version of EESASS Access database will be fixed during the future version of EESASS.
- ◆ *Design of the Source Tables:* As mentioned earlier, the current size of the EESASS database is about 26 MB and contains hundreds of tables and queries. There are 10-20 tables associated with each source and 20 such sources (which have more than 10 tables associated with it) are included in the EESASS database. In a future version, instead of having 10-20 tables for each source, a total of 20 tables will be designed for all sources. This will reduce the size of the database considerably. As the size of the database is reduced, the program will run much faster and thus will save considerable time. In addition, relationships can be established among the tables within the database, which will reduce the need to input data more than once.

- ◆ *Modification of Soil Texture Tables:* In the future version of EESASS, the assessor will be permitted to specify the areal extent of a particular soil texture by inputting polygon coordinates or by drawing areas on a site map with the pen, thus allowing the assessor to input more than one soil texture type. Other revisions may allow for vertical differentiation in soil textures.
- ◆ *Inclusion of Wind Rose Database:* Wind rose data include average wind speed for each of the 16 compass point directions and the percent of time that the wind blows from each of the 16 directions. These data will also be obtained from NOAA and will be linked to the nearest weather station with this information. The assessor will have the option of choosing another nearby weather station for default values or to override the default with site-specific values. Nearby stations can be identified with a pre-formatted query from the appropriate Risk GUI form.
- ◆ *Inclusion of Precipitation and Evapotranspiration (PET) Database:* Mean annual precipitation and evaporation-transpiration will be stored in the PET database. This data will be obtained from the National Oceanic and Atmospheric Administration, organized by weather station. The assessor will be permitted to override the default values by entering other values into the precipitation and ET fields on the appropriate forms.

(2) **Design of Multimedia:** The compatibility problem between the Visual Basic® and the camera will be fixed so that EESASS can utilize the complete multimedia capability of the software. This will result in more convenience for the assessor. The assessor will be able to capture multimedia while working on particular forms. The multimedia database table will store these files in the multimedia directory and send them to the appropriate sections of the report.

(3) **Development of the Interfaces:** As mentioned earlier, several interfaces between different modules of current EESASS need to be implemented to efficiently transfer data between them. Some of these include:

- ◆ Interface between DynaModules© and Microsoft Access© database to transfer GPS, environmental sensor, and bar code reader data between DynaMo© and Microsoft Access©.

- ◆ Interface between Microsoft Access<sup>®</sup> and ArcView<sup>®</sup> databases to transfer data between them automatically.
- ◆ Interface between ArcView<sup>®</sup> and the Report Generator so that the maps that are generated can be transferred to different sections of the report.

(4) **Preliminary Risk Assessment Program Modules:** More fate and transfer exposure models in PRP will be added, depending upon the availability of required mathematical equations.

(5) **Reporting and Documentation Program:** Several options of both electronic and paper reports will be included in the future version of EESASS. The following section described those options.

- ◆ **Electronic Reports:** Several options are available for producing electronic reports.
  - **Multimedia Reports:** These reports can include text, tables, graphs, maps, photos, video recordings, and sound clips. Simple clicking on an icon incorporated into the report text will cause the hyperlinked image to be displayed or clip to be heard.
  - **Multimedia Reports without Motion Video:** An option will be provided to exclude motion video from the final report. This option is provided in case there is limited storage or playback capacity available on the host machine.
  - **Multimedia Reports without Sound:** A second option to exclude sound files will also be provided to conserve storage and processing resources.
  - **Multimedia Reports without Photographs:** A third option allows the assessor to exclude photographs.
  - **Multimedia Reports, Text and Maps Only:** A fourth option allows the assessor to exclude video, sound, and photographs, leaving only text, tables, graphs, and maps. This will greatly conserve processing and storage resources and speed up display and scrolling speeds.

- Single Media Reports, Text Only: The simplest full electronic report is available by selecting the fifth option. This will generate a report that excludes all but text, tables, and graphs.
- ◆ Paper Reports: Paper reports will also be available for output. Three types of paper reports are offered.
  - Paper Report with Photographs: This paper report includes text, tables, graphs, maps, and photographs. This is the hard copy output version of the third electronic report option described above.
  - Paper Report, Text, and Maps Only: By selecting this option, the assessor receives a report without photographs. This is the hard copy version of the fourth electronic report option described above.
  - Paper Report, Text Only: The assessor receives the simplest full report style available by choosing this option. This is the hard copy version of the fifth electronic report option.



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