DOE/EH-0510

Technical Assistance Project

Environmental Guidance

Natural Resource Damage Assessment Implementation Project: Savannah River Site

October 1995

U.S. Department of Energy
Office of Environmental Policy & Assistance
RCRA/CERCLA Division, EH-413
Washington, D.C.

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United States Government Department of Energy

memorandum

DATE: October 26, 1995

REPLY TO
ATTN OF: Office of Environmental Policy and Assistance (EH-413):Bascietto:6-7917

SUBJECT: Technical Assistance Project: Natural Resource Damage Assessment Implementation Project; Savannah River Site

TO: Arthur B. Gould, Jr. Environmental Compliance Division, Savannah River Operations Office

The purpose of this memorandum is to transmit the results of a Technical Assistance Project (TAP), jointly undertaken between the Environmental Compliance Division (ECD) staff of the Savannah River Site (SRS), and the RCRA/CERCLA Division, Office of Environmental Policy and Assistance, Headquarters Department of Energy. The TAP report, "Natural Resource Damage Assessment Implementation Project: Savannah River Site" is attached for your information and use.

The TAP objective was to benchmark the process of integrating two key elements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), i.e., the natural resource damage assessment (NRDA) provisions (§ 107), with the remedial response provisions (§ 104). The suggested policy and procedures for integrating the two were first introduced via HQ DOE guidance cited in the attached report. Because the NRDA coordinator role at SRS resided with the ECD, your organization took the lead in assisting HQ DOE with the project.

This TAP produced the following general results:

- It provided a means to illustrate the use of complex analyses with real-time information on the specific natural resources of the SRS;
- It served as a vehicle for reinforcing and expanding the SRS personnel understanding of the links between CERCLA's NRDA and Remedial Investigation/ Feasibility Study (RI/FS) processes;
- It provided a forum for the discussion of strategic NRDA issues with SRS personnel; and,
- It allowed the refining and elaboration of DOE guidance by benchmarking the theoretical process using real information and issues.

This report does not attempt to analyze past or present conditions of natural resources at SRS, nor does it present the results of a NRDA. Furthermore, it does not draw or imply any conclusions regarding the need to assess potential natural resource damages at SRS. Rather, the report explores potential issues arising from the implementation of procedures developed by the EH-413 for DOE facilities that will be integrating CERCLA's NRDA requirements with CERCLA's response action process.

This TAP would not have been possible without the cooperation and technical guidance given to EH-413 by ECD, particularly Mr. Patrick Jackson. His contribution to DOE's innovations in the NRDA process will benefit the entire complex, as well as other Federal facilities performing CERCLA response actions. The attached report will be used as the basis for DOE recommendations to the U.S. Department of the Interior (DOI) in preparation for DOI's reproposal of the NRDA regulations at 43 CFR 11. This report will also serve as interim guidance to DOE facilities on implementing the policies and procedures for integrating CERCLA's NRDA provisions with its response actions.

If you have any questions or require further assistance with NRDA integration issues, or would like to discuss the attached report further, please contact Mr. John Bascietto of my staff at (202) 586-7917.

Thomas T. Traceski
Director, RCRA/CERCLA Division
Office of Environmental Policy and Assistance

Attachment

cc: DOE Natural Resource Trustee Steering Committee:
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TECHNICAL ASSISTANCE PROJECT

Natural Resource Damage Assessment Implementation Project: Savannah River Site

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CONTENTS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

A and M	administration and manufacturing
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Ci	Curie(s)
CV	contingent valuation
CVM	contingent valuation model
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EFT	effluent treatment facility
ERA	ecological risk assessment
FFA	Federal Facilities Agreement
ft^3/s	cubic ft/second
mgd	millions of gallons per day
MW	megawatt
NOAA	National Oceanic and Atmospheric Administration
NRDA	Natural Resources Damage Assessment
OU	operable units
PAS	preassessment screen
PRP	potentially responsible party
RA	risk assessment
RCD	restoration and compensation determination plan
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
RUM	random utility model
SRS	Savannah River Site
SWMA	separators and waste management area
TCM	travel cost model
UTRC	upper Three Runs Creek
WTP	willingness to pay

PREFACE

Environmental restoration activities mandated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) are currently underway at many U.S. Department of Energy (DOE) facilities. DOE is the CERCLA Lead Response Agency for these activities. Section 120 of CERCLA, as amended, could also subject DOE to liability for natural resource damages resulting from hazardous substance releases at these facilities. A Natural Resource Damage Assessment (NRDA) process (specified by the U.S. Department of the Interior's regulations at 43 CFR 11) is used to determine whether natural resources have been injured and to calculate compensatory monetary damages to be used to restore the natural resources. In addition to restoration costs, damages may include costs of conducting the damage assessment and compensation for interim losses of natural resource services that occur before resource restoration is complete.

Natural resource damages thus represent a potentially significant source of additional monetary claims under CERCLA. The requirements and procedures of NRDA have been described in detail elsewhere (DOE 1993; Sharples et al. 1993). The RCRA/CERCLA Division of the DOE Office of Environmental Policy and Assistance (OEPA) has developed a policy that calls for DOE facilities to integrate the NRDA and CERCLA processes. Such integration should result in improved environmental remediation decisions, reduced costs, and more rapid restoration of natural resource services.

In FY 1994, the Savannah River Site (SRS) was chosen to serve as a demonstration site for an NRDA Guidance Implementation Project. The OEPA tasked staff of the Environmental Sciences Division of the Oak Ridge National Laboratory and the Natural Resource Valuation and Assessment group of the Research Triangle Institute[1] to develop an NRDA framework for the SRS and demonstrate how NRDA concerns might be integrated into the environmental restoration activities of an actual site. This report summarizes the demonstration project activities and their results.

The demonstration project produced the following general results:

- It provided a means to illustrate the use of complex analyses using real information on the specific natural resources of the SRS.
- It served as a vehicle for reinforcing and expanding the SRS staff's understanding of the links between the NRDA and RI/FS processes.
- It provided a forum for the discussion of strategic issues with SRS personnel.
- It allowed the refining and elaboration of DOE guidance by benchmarking the theoretical process using real information and issues.

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[1] The staff from the Research Triangle Institute are now with Triangle Economic Research.

1. INTRODUCTION

The U.S. Department of Energy (DOE) is both a trustee for the natural resources present on its properties and a responsible party liable under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for injury, destruction, or loss of those resources caused by releases of hazardous substances from its facilities (DOE 1991). As a CERCLA Lead Response Agency, DOE is also responsible for collecting data to be used in determining the extent of contamination at its facilities, estimating risks to human health and the environment, and selecting appropriate remedial actions. The remedial investigation/feasibility study (RI/FS) process is used to investigate sites and select remedial actions. A Natural Resource Damage Assessment (NRDA) process is used to determine whether natural resources have also been injured by the released hazardous substances and may be used to calculate compensatory monetary damages for restoring the natural resources. In addition to restoration costs, damages may include the costs of conducting the damage assessment and compensation for interim losses of natural resource services that occur before resource restoration is complete. Thus, natural resource damages represent a potentially significant source of additional monetary claims under CERCLA.

Because the RI/FS and NRDA processes share some common purposes and procedures, the RCRA/CERCLA Division (EH-413) of the DOE Office of Environmental Policy and Assistance (OEPA) has developed a policy that calls for DOE facilities to integrate the NRDA and CERCLA processes. Integration of the NRDA and CERCLA processes should result in improved environmental remediation decisions, reduced costs, and more rapid restoration of natural resource services using the following rationale. An NRDA is usually not conducted until after a Record of Decision (ROD) has been issued in a CERCLA action, i.e., when a remedy has been selected and the degree of residual injury to natural resources can be more precisely determined. But for large, complex sites like the DOE reservations, it is not unlikely that starting the collection of data for NRDA purposes after the issuance of a ROD might require several years of additional effort beyond the RI/FS. Because DOE is both a lead response agency and a trustee for natural resources, DOE has the opportunity to integrate the RI/FS and NRDA processes, so that data suitable for both can be collected during the RI/FS. Integrating in this way can increase the cost-effectiveness of environmental restoration activities in two ways. First, expanding the RI/FS data collection effort to accommodate NRDA concerns can minimize the need for repeated sampling of the same resources. Second, considering the relationships between remedial action alternatives and natural resource damages provides an opportunity to select remedial actions that minimize or avoid natural resource damages and reduce the total costs of remediation plus restoration.

The purpose of this NRDA guidance implementation project was to develop a framework for implementing this integration policy for an actual DOE site. The NRDA process is, for the most part, designed to be used in simple situations involving single contaminant sources for which the entire cleanup process can be completed in a relatively short period of time. In contrast, most DOE facilities contain many diverse contaminant sources and cleanup is expected to take decades. Thus, applying the NRDA process and integrating it with CERCLA activities at such sites represents a substantial challenge and requires some development and demonstration of methods. The Savannah River Site (SRS), which is characteristically large and complex, was chosen as the location of the first demonstration project.

The Environmental Sciences Division of the Oak Ridge National Laboratory and the Natural Resource Valuation and Assessment group of the Research Triangle Institute, who are now with Triangle Economic Research, were tasked to develop the integration framework. Most phases of the project also involved substantial collaboration among project personnel and SRS staff.

Four meetings were held at the site. An initial planning meeting was held on May 4-5, 1993. Each meeting after this initial one was then used to address the various phases of an NRDA and how they might be conducted in sequence for SRS. A "preassessment screen" (PAS) workshop was held on July 7–8 to work through a prototype NRDA PAS for the site and to synthesize information about the status of the natural resources at SRS. A workshop to develop a conceptual model for ecological risk assessment (ERA) injury determination using a "reference watershed" at the site was held on October 28–29. A final workshop, which covered quantification of service losses, determination of damages, and an integration summary was held on March 2–3, 1994.

This report summarizes the demonstration project activities and their results. It is intended to describe a general method for or approach to integrating NRDA and RI/FS activities that is transferable to other DOE facilities. The demonstration project produced the following general results:

- It provided a means to illustrate the use of complex analyses using real information on the specific natural resources of the SRS.
- It served as a vehicle for reinforcing and expanding the SRS staff's understanding of the links between the NRDA and RI/FS processes.
- It provided a forum for the discussion of strategic issues with SRS personnel.

- It allowed the refining and elaboration of DOE guidance by benchmarking the theoretical process using real information and issues.

2. PREASSESSMENT SCREEN AND ASSESSMENT PLAN PHASES

2.1 PREASSESSMENT SCREEN

The PAS phase of NRDA was addressed at the July 7–8, 1993, meeting via a presentation and discussion exercise. The first part of the presentation reviewed important basic points about the NRDA process (e.g., roles of trustees, liability exclusions, definitions, etc.) and the general characteristics of a PAS (purpose, questions to be answered, etc.). Information on four actual PASs prepared for private sector sites with issues comparable to those at SRS (Table 1) was then presented. Features common to all of them included area descriptions, information on contaminants and contaminant sources, identification of potential/probable pathways of exposure, identification of potentially injured resources, and answers to the five PAS questions/requirements. These items constitute the basic information set needed for a PAS. Structure, emphasis, and level of detail differed among the documents because of site specific influences, and only two of them addressed the issue of liability exclusions.

Table 1. PAS examples

Location	Substances released	Source of release(s)
Clark Fork river basin in western Montana	Copper, arsenic, mercury, and other hazardous substances	Mining activity
St. Lawrence River near Massena, New York	PCBs[a], metals, and other chemicals	Aluminum plants
Los Angeles bight	PCBs and DDT[b]	Municipal sewer outfalls
Savannah River near Savannah, Georgia	500,000 gal of oil	Tanker

[a]PCB = polychlorinated biphenyl
[b]DDT = dichlorodiphenyl-trichloroethane

A four-step framework was recommended if SRS were to prepare a PAS document:

- acquire/assemble needed information;
- address the five PAS questions;
- evaluate liability exclusions; and
- develop the document.

A proposed outline for an SRS PAS was discussed, as were other PAS issues such as cotrustee involvement, timing, and funding.

2.2 ASSESSMENT PLAN

The October 28–29 meeting was opened with a discussion of the NRDA assessment plan phase. The purpose of an assessment plan is to identify the methodologies to be used to determine whether natural resources have been injured, quantify loss of services, and calculate damages. In an integrated RI/FS-NRDA, the assessment plan could also be used to document how the two processes are to be coordinated. In fact, assuring that the assessment plan makes maximal use of RI/FS data and that the gaps in RI/FS data, from the NRDA standpoint, are identified and filled were designated as critical issues for integration of the processes.

As was done for the PAS phase, information on a comparison of several real assessment plans was also presented and discussed. Major sections of an assessment plan include descriptions of the circumstances of the case (affected area, resources, etc.), determination of assessment type, plans for coordination with RI/FS, procedures and schedules for sharing data among trustees, sources of hazardous substances, exposure of resources, research plan, and restoration and compensation determination (RCD) plan. The last item is to provide estimates of damages, which can be compared to costs for the assessment to assure that assessment costs do not exceed damages. The RCD plan has also been designed by the U.S. Department of the Interior (DOI) to serve as the step in which a restoration alternative is selected. The timing of this step can, however, be delayed if insufficient information is available before injury and damages determinations are performed.

The remainder of the October 28–29 meeting dealt in detail with the technical process involved in integrating injury determination with ERA, which is covered in the following section.

3. INTEGRATING THE ECOLOGICAL RISK ASSESSMENT AND INJURY DETERMINATION STEPS

This section describes the development of conceptual models that would allow integration of the ERA portion of the RI/FS and the injury determination step of NRDA. The construction of such a model for selected portions of the SRS is also illustrated. The conceptual model identifies the potential linkages between releases of hazardous substances, pathways of exposure, receptor natural resources, and potential injuries to the natural resources due to these exposures. Development of the SRS example was based on intensive discussions with the SRS staff on October 28–29. These discussions helped identify sources of available data for SRS, as well as areas of data gaps/needs.

3.1 TECHNICAL APPROACH

Complex sites, such as DOE facilities, usually contain many different sources and types of contamination. Implementation of CERCLA at such sites usually involves identification of discrete sites or groups of closely-related operable units (OUs) that (1) contain the same or similar contamination and (2) can be treated using the same technology. Independent RIs, risk assessments (RAs), and FSs are performed for each OU. Although convenient from an engineering perspective, independent investigation of individual OUs can be illogical from an RA perspective because the human and ecological receptors at risk from contamination are often exposed to contamination from multiple sources. Moreover, contaminated sites such as groundwater plumes and stream sediments are usually sinks for contaminants originating at other locations (e.g., trenches and tanks) and cannot be successfully remediated until the original sources of contamination are identified and closed. For this reason, some DOE facilities are adopting iterative approaches to CERCLA implementation in which primary sources of contamination (source control OUs) are distinguished from secondarily contaminated areas (integrator OUs) that accumulate contaminants originating at many points (Suter and Loar 1992; DOE 1994).

When an iterative strategy is employed, RAs are performed in a sequential, hierarchical manner. Source control OUs typically have little ecological significance in themselves; detailed ecological evaluations are performed at these sites only if a preliminary evaluation demonstrates a clear risk to endangered/threatened species or other ecological resources of high concern to regulatory agencies. Integrator OUs, in contrast, are likely to be large, ecologically significant areas (streams, floodplains, forests) that contain important ecological resources. These sites should receive detailed ecological investigation to monitor improvements resulting from remediation of source control OUs and to determine the need for further remediation. If properly coordinated, watershed or landscape-scale ecological investigations can actually benefit the source control OU programs by providing data needed to quantify the ecological benefits derived from eliminating off-OU contaminant migration. Such information is obviously valuable for a feasibility study that must compare the costs and benefits of alternative remediation approaches.

If NRDAs are performed at DOE facilities, it will be at the integrator-OU or sitewide scale because this is the scale at which natural resource service losses and damages are most quantifiable. The approach recommended in this document is for a facility to adopt a strategy in which watershed-level or landscape-level ecological data collection programs provide information that can be used both for CERCLA activities and for NRDAs.

The first steps in the NRDA process involve identification of "resources of concern" by Natural Resource Trustees. The purpose of this list is to eliminate resources that are not injured and to focus efforts on resources that the cotrustees think are important, either due to their rarity, economic value, or general value to the public. This list serves as a starting point for the purposes of identifying NRDA concerns at DOE facilities and may be modified as circumstances require. The resources identified are functionally equivalent to the "assessment end points" (Suter 1993; EPA 1992) in CERCLA ERAs. This presents a potential conflict with the RI/FS process, because assessment endpoints for CERCLA may already have been identified in a Federal Facilities Agreement (FFA) signed by DOE, the U.S. Environmental Protection Agency (EPA), and state regulatory agencies. Although resources protected by statute (e.g., endangered species and wetlands) or identified as "of concern" in public scoping meetings usually will be included both in the FFA and in the trustees' resources of concern, the two lists may not be identical.

Once resources of concern are identified, the conceptual model that links the resources of concern to the known or suspected sites of contamination needs to be developed. According to EPA's Framework for Ecological Risk Assessment (EPA 1992), the conceptual model "describes how a given stressor might affect the ecological components in the environment" and "describes the relationships among the assessment and measurement end points, the data required, and the methodologies that will be used to analyze the data." In short, the conceptual model provides the framework for designing an assessment and interpreting the results.

For the integrated approach discussed here, two levels of conceptual models are needed. A site-level model (Fig. 1) displays the relationships between the various OUs present at the site and the various resources potentially affected by contaminants from those OUs. The site-level model identifies the specific resources potentially affected by each OU so that appropriate information

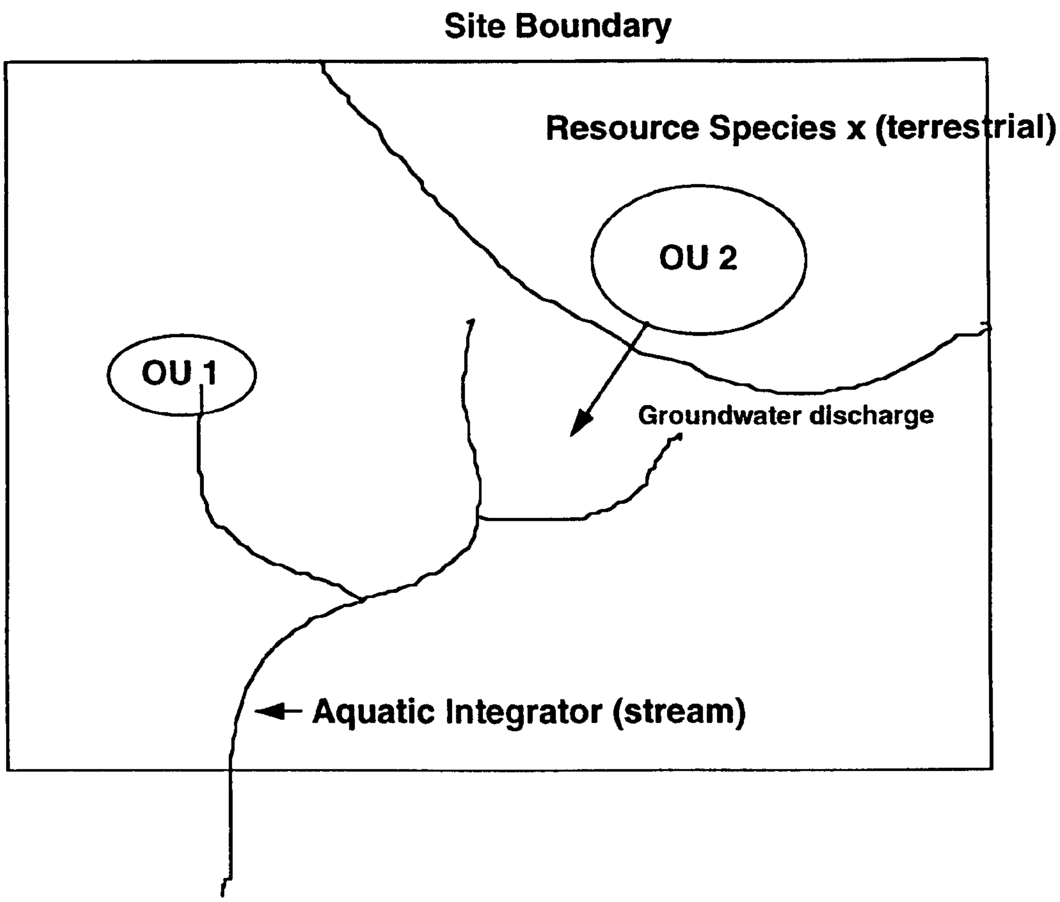

Fig. 1. Site-level conceptual model showing operable units (OUs) and potentially affected resources.

can be gathered during OU-specific field studies (e.g., contaminant concentrations in vegetation grazed by deer moving through the site). The site-level model also facilitates identification of all of the OUs potentially affecting each resource, so that studies of resource condition can be focused on the most exposed resources and locations.

OU-level models identify the specific pathways by which resources could be affected by each contaminant source. Figure 2 presents a generic conceptual model of a lake or stream containing contaminated sediment. It graphically represents environmental pathways for fish, birds, and mammals that would be typical resources of concern exposed to contaminants derived from the sediment. The exposure pathways identified in the conceptual model provide a guide to selection of (1) the specific types of field data required for the assessment and (2) the spatial locations from which measurements are needed. The conceptual model can also be used to identify the types of service losses and potential damages that may require investigation. Creation of the conceptual model should also allow the trustee to determine what data exist and who on the site created and has access to the data. Typical types of data useful for injury determination include (1) concentrations of contaminants in environmental media, (2) contaminant body burdens in natural resource species or in organisms important as food for those species, (3) other evidence of injury to natural resource species (deformations, biomarker responses, or other data specified in NRDA regulations), and (4) abundance or use of the resources that could be used for determining service losses.

The spatial distributions of natural resources have an important influence on the design of data collection programs needed for injury determination. Resources such as soil and vegetation are permanently fixed in space. Small mammals often occupy home ranges that are small compared to the size of a typical OU. Most of the data required to support injury determination in location-specific resources can be obtained from OU-level studies. Large, mobile animals such as deer, migratory waterfowl, and anadromous fish migrate over long distances and can be exposed to contaminants from multiple OUs. Injury assessments for wide-ranging species require watershed-level or facility-wide studies to determine habitat distribution/use patterns, spatial distributions of contaminant exposure, and the contributions of different OUs to total resource exposure. Much of this information may already exist. Compliance-related environmental monitoring programs and reservation management programs typically collect information on aquatic ecosystems, vegetation, soils, wildlife, and endangered species. Geographic information systems that can summarize these data in resource maps either exist or are being developed at many DOE facilities. Once a conceptual model is developed, the next step for the technical analyst is to survey all of the existing data for a reservation and determine whether gaps exist.

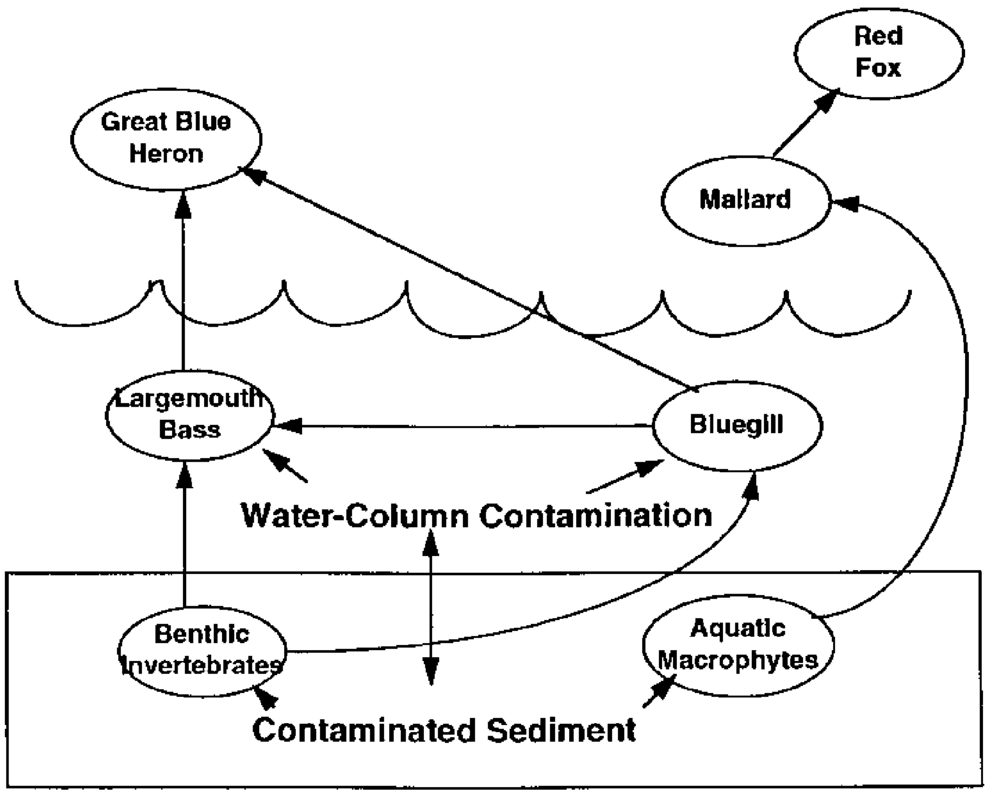

Fig. 2. Resource-level conceptual model.

Once the data have been obtained, a variety of techniques are available for quantifying the relationships between contaminant exposures and resource injuries (e.g., Bartell et al. 1992; Suter 1993). For the most part, these are the same methods used to quantify exposures and effects for CERCLA ERAs. Assessment methodologies for CERCLA sites are rapidly evolving and, although no formal guidance exists, case studies are now being published in Environmental Toxicology and Chemistry and several other scientific journals.

3.2 STATUS OF NATURAL RESOURCES OF THE SRS

The SRS occupies about 300 mile^2 (192,323 acres) in South Carolina. The site is bounded on the southwest by the Savannah River and is about 25 miles southeast of Augusta, Georgia (Fig. 3). Elevation of the ground surface of the site and the immediate surroundings varies between 90 and 340 feet above mean sea level. The area surrounding SRS is mostly rural and agricultural.

3.2.1 Geological Resources

SRS is located on the Upper Atlantic Coastal Plain, approximately 20 miles southeast of the fall line that separates the Piedmont and the Coastal Plain provinces. The site is on the Aiken Plateau, a relatively flat area that slopes southeastward and is dissected by several tributaries of the Savannah River. SRS is underlain by a 700 to 1200 feet thick wedge of Coastal Plain sediment. This sediment is composed of unconsolidated sandy clays, clayey sands, and lesser amounts of calcareous sediment. These layers are underlain by dense crystalline igneous and metamorphic rock or consolidated sediments of the Triassic period. Within the Coastal Plain sediments, the sandy strata are generally porous and permeable and are aquifers The clayey strata are less permeable and tend to be aquitards.

The dominant texture of the surface horizons is loamy sand. Slopes typically range less than 12%, and most soils are well drained. Streambed soils of the Pen Branch, Four Mile Branch and Steel Creek consist primarily of sandy loam and have been scoured and eroded by reactor operations.

3.2.2 Groundwater

Groundwater beneath the site flows slowly with rates ranging from only inches to several hundred feet per year. Groundwater travels toward streams, swamps and the Savannah River and is recharged by rainfall.

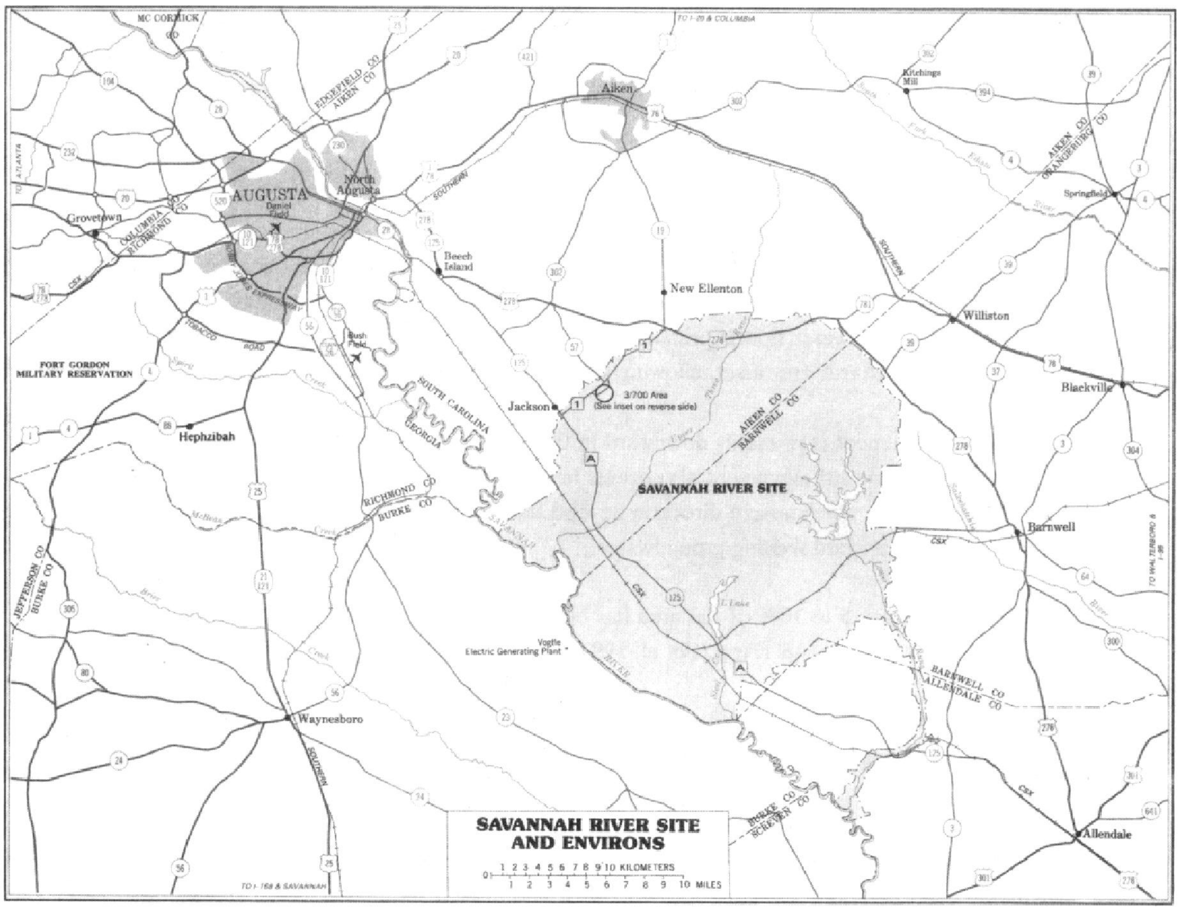

Fig. 3. of the River Site.

Three aquifers are found under SRS. The deepest is the Cretaceous-age Tuscaloosa formation whose sediments are large sandy-clays and quartz sands that yield large amounts of water. This aquifer occurs on both sides of the Savannah and drains into the Savannah River. The second aquifer, Congaree-Four Mile formation, is composed of Eocene sediments that have sandy-clay and moderately to well separated sand constituents. This aquifer flows toward or empties into Three Run Creek or the Savannah River depending upon which is closer. The third aquifer is the upper saturated zone and is composed of sandy clay and calcareous sediments. The aquifer includes the Hawthorne, Barnwell, and McBean formations. This aquifer empties into the nearest perennial stream, the swamp, or river-making, complex local groundwater flow patterns (Arnett et al. 1992).

Few aquitards in the SRS are continuous across the site. In the northwestern portion of SRS, near the administration and manufacturing (A and M) areas, aquitards are less continuous and allow vertical flow of groundwater. In the southeastern portion of SRS the aquitards are more continuous and groundwater flow is primarily vertical. Along the Pen Branch fault, which nearly bisects the SRS, aquitards are offset, allowing vertical movement of groundwater.

Groundwater movement is primarily downward in the northwestern section of SRS around the A and M Areas. Downward movement also occurs in a wide band from L Lake to the separations area and extends in a northeastern direction beyond the site boundary. The remainder of the site is characterized by upward moving groundwater.

Groundwater beneath 5 to 10% of the area has been contaminated by industrial solvents, tritium, metals, and other constituents (Arnett et al. 1992).

A study conducted in 1979 identified all users of groundwater pumping in excess of 5000 gallons per day within a 20-mile radius of the SRS. Researchers identified 38 groundwater users pumping in excess of 22 million gallons per day (mgd) combined. Of the 38 users, 8 were facilities at the SRS that pumped over 6 mgd, 19 were municipal users that pumped over 8 mgd, and 11 were off-site industrial users who used over 8 mgd. Most users draw their water from the Tuscaloosa formation. The exceptions are three municipalities who draw from the Congaree and McBean formations.

3.2.3 Air

SRS and the surrounding area receive emissions from the facilities on-site, the Vogtle Power Plant, and various non-point sources. Generally, the air is clean; recent noncompliance problems have been readily eliminated and are related to secondary equipment, i.e., noncompliance with permit due to elevated particulates from a backup diesel generator. Tritium is the largest component of air emissions from the plant, but other components are NO_x, CO, and SO_x from an on-site 175-MW power plant. No chronic or pervasive emission problems have been identified.

3.2.4 Surface Water

Surface waters within SRS include 28 natural ponds, two man-made ponds (Par Pond and L Lake), and 189 Carolina bays. Mean pond area is 17.6 acres, excluding Par Pond (2700 acres) and L Lake, with a range of 0.4 to 202 acres. The mean Carolina Bay area is 6.6 acres with a range between 0.3 and 124 acres. Approximately 7400 acres of the total area of SRS is covered by surface water.

The Savannah River adjoins SRS for 17 miles. The average flow rate of the Savannah River is 10,200 cubic feet per second (cfs). SRS pumps water from the Savannah River at a maximum rate of 920 cfs to supply cooling water to C, K, and L reactors. About 20 cfs goes to Par Pond to compensate for seepage and evaporation. These pumping stations impinge an average of 6500 fish annually when reactors are in operation. Future impingement is likely to be reduced since one of the three reactors has been put on cold standby and overall water requirements are lower than when impingement numbers were estimated. This impingement is not considered significant compared to the density of fish population in the Savannah River.

Five major streams from SRS feed into the Savannah River: Upper Three Runs, Four Mile Branch, Pen Branch, Steel Creek and Lower Three Runs (Fig. 4). Pen Branch and Four Mile Creek have a normal flow rate of 5 to 10 cfs. When receiving discharges from reactors, the flow has been recorded 10 to 12 times above normal and with water temperatures 35°C above normal. Each of the five streams have received discharges from various SRS operations and are not used as commercial water sources.

Aquatic life in surface water has been found to be more diverse in the number of taxa than in similar waters in the region. Over 100 taxa of zooplankton occur in L Lake with 115 taxa in Pond B, and 164 taxa in Par Pond. Forty-eight species of fish have been found in various reaches of streams on SRS. Yellowfin shiner, spotted sunfish, bluehead chub and pirate perch are among the dominant species in SRS streams. The Savannah River is used for recreational fishing and boating. Commercially or recreationally valuable biota that occur in the Savannah River include the American shad, channel catfish, Atlantic sturgeon, sunfish, bream, and striped bass. No commercial fishing is allowed within SRS. Bream, redbreasted sunfish, and catfish are the dominant fish caught in the region. Bream and largemouth bass are the primary species for anglers' effort.

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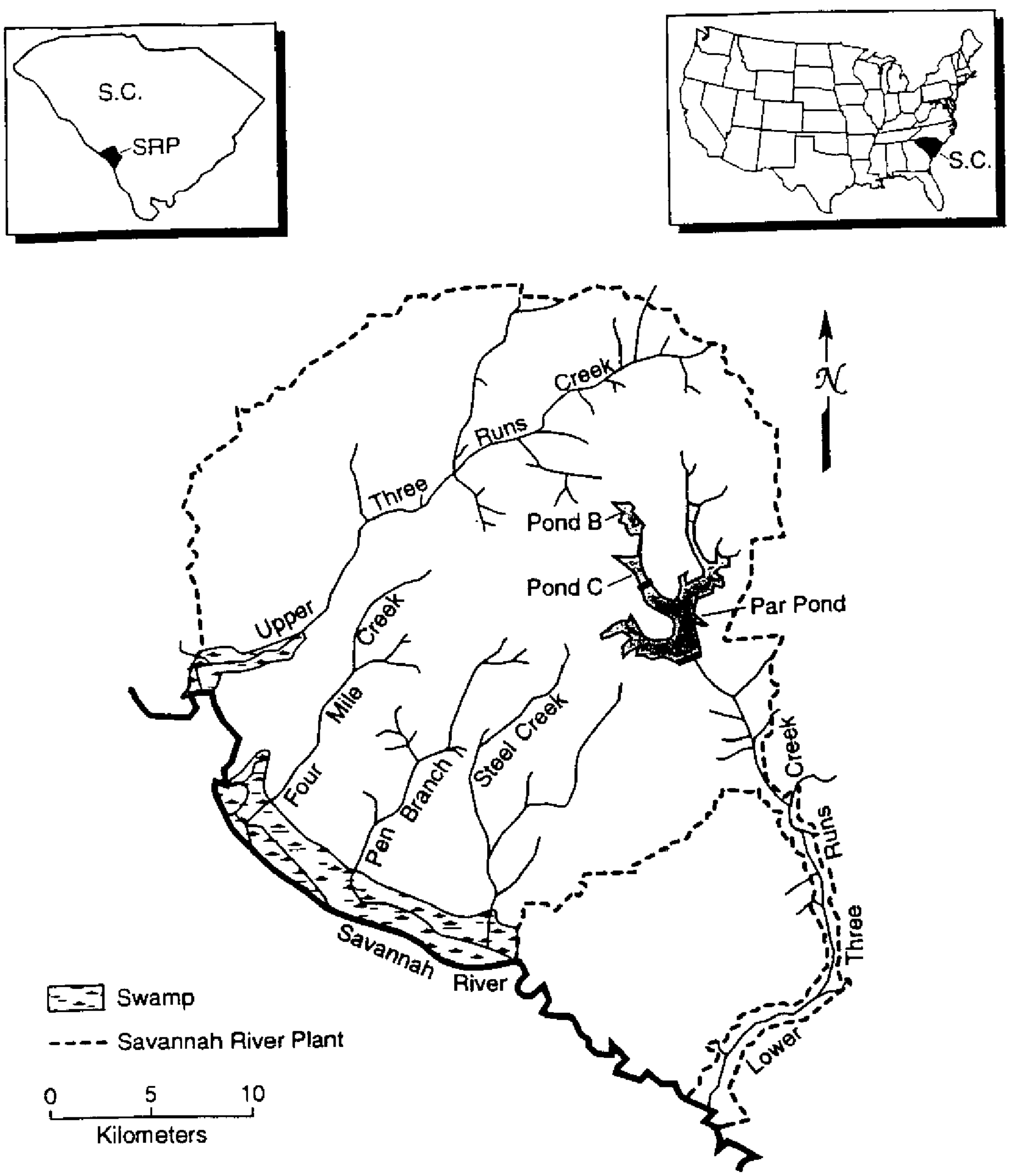

Fig. 4. Major features of the Savannah River Site.

3.2.5 Wetlands

Wetland occurs on over 15,000 acres of SRS. About 64% of the wetlands are bottomland hardwood forests that occur primarily along streams and in the Savannah River Swamp. Fourteen percent of the wetlands are Cypress-Tupelo swamp forest, located mostly in the swamp. Scrub-scrub and emergent marsh areas are found in the thermal and postthermal areas where discharge carrying streams enter the swamp.

The Savannah River Swamp within SRS runs along the Savannah River for about 10 miles and is approximately 1.5 miles wide. A natural levee separates the swamp from the river. At various times, river water overflows the levee and floods the entire swamp area. On average the river overflows into the swamp 22% of the time. Three major breaches in the levee allow creek water to flow into the river—the mouths of Beaver Dam Creek, Four Mile Creek and Steel Creek.

Another common wetland surrounds the many Carolina bays found in SRS. These bays range from a few hundred feet long to four miles in length. Some of the bays remain inundated year round while others have dry bottoms in periods of low rainfall. These periodically dry bays frequently have wetland vegetation covering the entire bottom of the bay.

3.2.6 Forests and Land Cover

The land surface of SRS is dominated by pine and pine plantations (64% of total acreage) and other stands of timber, with over 80% of SRS being forested. Five land cover/forest types occur. (1) Grassland/forb land, a type dominated by nonwoody plants, grasses, and forbs, composes more than 50% of the ground cover. This type primarily occurs on power line right-of-ways and in a few forest openings. (2) Scrub-scrub includes timberland where the trees have been recently cleared and less than 10% canopy cover occurs. This type usually has seedlings and saplings under 5 years old and less than 6 meters tall. (3) Upland forests, areas where the trees are at least 6 meters tall, include evergreen and deciduous forest land. Evergreen areas are dominated by loblolly or longleaf pine. Deciduous areas have at least 70% deciduous canopy cover. Drier sites are dominated by oak while moister sites are oak/hickory. Low slope sites also include tulip tree, red maple, sweet gum, and holly, as well as oak and hickory species. (4) Bottomland hardwood forests occur primarily in the drier areas of the Savannah River swamp and near the various streams on SRS. Canopy species include water oak, laurel oak, elms, red maple and tulip tree. (5) Cypress-Tupelo occurs predominantly in the Savannah River Swamp. These areas are characterized as being wet and dominated by bald cypress and water tupelo.

The Forest Service manages over 174,000 acres of commercial forest land on-site with a net merchantable volume of 797 million board feet of saw timber and 2690 million cords of pulpwood as of 1987. Most of the timber is drawn from stands of upland hardwood and pine plantations or stands. The estimated value of standing timber was over $118 million in 1987, with timber sales of $1.6 million that year. Except for small outcroppings of contamination near Four Mile Creek, facility operations have had little effect on timber productivity.

The area surrounding SRS is primarily agricultural. Soybeans, corn, cotton, and other small grains are the dominant crop types. Much of the SRS is agricultural land that has been undisturbed since the establishment of the plant and allowed to return to ecological natural succession.

3.2.7 Wildlife

The SRS supports diverse woodland and wetland ecosystems, which have become established over the past 40 years due to the relatively undisturbed nature of the site. It is the largest tract of timberland in the area, and its protected status has allowed the reestablishment of native woodland species. A wide variety of wildlife can be found at SRS: 16 or 17 salamander species; 25 or 26 frogs and toads; 11 turtles; nine lizards (including the alligator, which is federally-listed as a threatened species); and 31 or 32 snakes. Early research identified 213 bird species, and large numbers of waterfowl have used the area since it has been closed to the public. SRS is also heavily used as an overwintering site for various migratory bird species affected by habitat loss elsewhere along the flyway.

Forty species of mammal have been observed at SRS. Eight other species, although not known to occur, could occur because of the presence of appropriate habitat, including cougar, swamp rabbit, big brown bat, and hoary bat. Fifteen game or furbearing mammals of commercial or recreational value occur at SRS, including white-tailed deer, bobcat, mink, and feral pig. Their populations have been known to vary widely. The estimated population of white-tailed deer on SRS has been 3500 for the past two years. Regulated white-tailed deer and feral pig hunts are conducted to help control their populations. This is the one exception to the fact that SRS is closed to the public and little direct recreational use occurs on-site. The 1991 hunt yielded 1092 deer and 126 hogs, while the 1990 hunt yielded 1071 deer and 132 hogs. Each individual killed is monitored for contamination and thyroid and muscle samples are taken from 10% of the kill for laboratory analysis for radioactive contaminants. Kills near the human exposure limit are confiscated.

Ten areas within SRS have been set aside as research areas. Adverse impacts to these set aside areas would detrimentally affect the scientific research being conducted.

3.2.8 Endangered and Threatened Species

The habitat provided by SRS is unique in many ways and supports 31 species classified as sensitive, threatened, or endangered. Eight are federally listed and seven are state listed. Five federally endangered species will be discussed here.

Several federally listed threatened or endangered bird species frequent SRS and two have nesting sites there. Thirty-six bald eagle individuals have been observed on the site, mostly around Par Pond and L Lake. A single active nest containing two juveniles was located below Par Pond Dam in 1986. After an intensive management program to promote nest sites, 30 red-cockaded woodpeckers, living in nine clusters of cavity trees, currently inhabit SRS. This number is up from the 11 individuals known in 1986.

Another endangered avian species that frequently uses the SRS is the wood stork. Although no nesting storks have been observed on the SRS, there is a nesting colony 35 km southeast of SRS. Wood storks have been observed foraging in the Savannah River Swamp, and their foraging habitat is affected by the thermal effluent from the SRS reactors entering the swamp and causing localized wetland changes. Increased foraging habitat was created in Kathwood Lake 10 km northwest of SRS and 45 km north of the nesting colony. Further loss of foraging habitat at SRS may affect the recovery of this species.

A fourth endangered species known to inhabit SRS is the shortnose sturgeon. Larvae of this species have been collected near the SRS pump houses. Little is known about its life history, especially those inhabiting southeastern waters. No shortnose sturgeon have been found in impingement studies from SRS pump houses. However, one Atlantic sturgeon has been found and the possibility exists for shortnose impingement from SRS pumping activities. The Savannah River and the Savannah River Swamp are both habitats for the shortnose sturgeon and SRS activities may directly affect individuals or their habitat.

The fifth threatened species is the American alligator. Individuals have been observed on Par Pond, Beaver Dam Creek and in the Savannah River Swamp. Estimated populations of alligator have gone from 110 adults and juveniles in 1974 to 197 individuals in 1988. The population in Par Pond has nearly doubled in the past 14 years. As existing populations have increased during reactor operations, continued operation of the reactors at SRS is not likely to have an effect on the alligator population.

3.3 DOCUMENTED RELEASES OF HAZARDOUS SUBSTANCES

The SRS is divided into six major areas of operation. The reactors are designated C, K, L, P, and R. None of the reactors has operated since 1988; however, a start up of K reactor occurred in 1991, and it may be in use currently. R reactor was permanently shutdown in 1964, and P reactor was permanently shutdown in 1988. C, L, and K reactors are on cold standby with K being restarted. The reactor facilities release effluent containing tritium, ^{137}Cs, ^{90}Sr, and other transuranic isotopes into SRS streams and the Savannah River. These facilities also emit radioactive material, primarily tritium, into the air. No nonradiological standards were exceeded by reactor areas in 1991. The reactor materials or M area produces fuel and target assemblies for the SRS reactors and has a treatment facility for radioactive liquid wastes. This area is located in the northwest portion of the site. The wastewater treatment facility discharges into the Tims Branch, which feeds into upper Three Runs Creek. This area has been in limited use since the shutdown of the reactors in 1988. This area released small amounts of ^{90}Sr, ^{235}U, and ^{238}U as liquid effluent in 1991.

The separations area is centrally located within the facility. Products made in the reactors are chemically separated in F and H areas. Discharges from this area, primarily tritium, enter Four Mile Branch. Waste management areas are scattered throughout the facility and include the F- and H-area effluent treatment facility (EFT), the M-area EFT, the high-level waste tank farms, the defense waste processing facility, and the solid waste disposal facility (formerly the radioactive waste burial grounds). These facilities are located centrally except for the M-area EFT, which is located in the northwest portion of the site. The heavy water reprocessing area is located in area D in the southwest portion of the complex. This area also contains a coal-fired power plant. This area releases tritium into Beaver Dam Creek. Discharges range from 1700 Ci when the area is operational to below 400 Ci when inactive. The coal plant releases various emissions common to coal-fired plants, and no exceedances from power plant operations were recorded in 1991. The administration area (A area) contains the DOE site operations office, the Savannah River Ecology Laboratory, the Savannah River Laboratory, and the U.S. Savannah River Forest Station headquarters. This area is located near the northern boundary of the SRS.

More than 300 sites at the SRS are being evaluated to determine whether further investigation is necessary, and 102 waste sites are now being investigated under CERCLA. Wastes in these sites include petroleum products, chlorinated solvents, heavy metals, radioactive sludges and radioactively contaminated solid wastes, polychlorinated biphenyls, and other hazardous substances. Other nonradioactive releases include emissions from the D area power plant and on-site machinery such as diesel generators.

The primary sources of nonradiological releases are from the various waste-management seepage basins, burial pits, and burning pits found in the M, H, and F areas. Most of these sources were closed in the late 1970s or early 1980s. Waste was deposited in many of these sites from the beginning of facility operations. The distribution of waste, the severity of contamination, and the amount of waste in these sites is very heterogeneous, making the sites difficult to characterize. Many of the hazardous waste sites contain a mixture of radioactive and nonradioactive waste and this mixture has entered the groundwater from a number of these sites.

3.4 POTENTIAL NATURAL RESOURCE INJURIES

3.4.1 Groundwater Resources

Arnett et al. (1992) described ten large areas where monitoring wells had constituents exceeding drinking water standards in 1991. The largest areas of contamination were in the A and M areas, located at the northeastern portion of the site, and the separations and waste management area (SWMA) that included the H and F areas, located centrally. Localized contamination was found at 25 monitoring sites with clustering of these sites in area C, which is south of the SWMA, and B area, which is west of the SWMA.

Common contaminants in the two large groundwater plumes under the A and M areas and the SWMA include chlorinated volatile organics such as trichloroethylene and tetrachloroethylene, heavy metals, and radionuclides. The plume beneath A and M areas was composed primarily of trichloroethylene but included other chlorinated solvents and total radium and tritium in concentrations above the drinking water standard. Common metal contaminants found in test wells at the two large area sites were lead, mercury, antimony, chromium and cadmium. Other contaminants included sulfate, nitrate, tritium and other radionuclides like ^{137}Cs, ^{238}U, ^{235}U, and total radium.

Outcropping of groundwater from the H and F areas into Four Mile Creek and the surrounding wetland directly below the direction of groundwater flow has been cited as the probable cause of tree mortality. This mortality was likely due to elevated levels aluminum, manganese, cadmium and zinc.

3.4.2 Surface Water

There are two man-made standing bodies of water on the site, L Lake and Par Pond, 28 known natural ponds and 189 Carolina bays. Both of the man-made ponds received cooling effluent from reactors in the past, as did Ponds C and B. Currently, levels of radioactivity are relatively low, and no effluent is being discharged into these ponds. Most of the radioactive isotopes have partitioned to the sediments and shoreline soils of these sites.

Five stream systems on the site drain into the Savannah River: Pen Branch, upper Three Runs, Four Mile Creek, Steel Creek and lower Three Runs. Each has received radioactive waste effluent in the past, with Four Mile Creek having received the most effluent recently.

Elevated tritium levels occur because of outcropping of groundwater from the H and F areas into Four Mile Creek. These levels were three orders of magnitude above the background level and greater than the DOE derived concentration guideline standard of 2.0×10^{-3} mCi/ml. However, contamination levels tended to be localized. Tritium levels above the DOE standard were also found in upper Three Runs Creek. This stream drains the H and F areas and receives effluent from the ETF located in area H. As with the Four Mile Creek tritium outcropping, contamination was localized (Arnett et al. 1992).

Radioactivity in the Savannah River was not significantly above the upstream activity levels in 1990. However, previous levels of activity were likely to have been higher.

3.4.3 Soil and Sediments

Pond B and Par Pond, into which Pond B drains, both contain "elevated levels" of ^{137}Cs in sediments. The maximum radioactivity levels in Par Pond sediment were 135 pCi/g from ^{137}Cs. Contamination from ^{137}Cs was also found in the Savannah River Swamp soil which ranged from background levels to 280 pCi/g in 1991 and 155 pCi/g in 1989 (Table 11-1). Sites of high activity tended to be localized within a few hundred meters of the sample. Concentrations of ^{137}Cs in a 1990 survey of Four Mile Creek were found in soil at 136 pCi/g. No direct toxicity data were available from this area (Arnett et al. 1992).

Radioactive contamination and hazardous waste contamination of surface soils are likely in the F- and H-area seepage basins and burial ground. The types of contaminants found at this site have already been mentioned under groundwater. Although no direct evidence was listed in the literature reviewed, organisms that inhabited these localities may have been injured by the wastes in these areas. The same can be said for other CERCLA operational units at SRS.

3.4.4 Wildlife and Vegetation

Mercury levels above the 1 μg/g standard have been found in various fish species, but were most prevalent in bass. Fish with above standard mercury levels occurred in Par Pond, lower Three Runs Creek, Steel Creek, and the Savannah River adjacent to SRS.

Deer and hog taken on the reservation during regulated hunts have exhibited levels of contamination in muscle that are below the effective dose equivalent to cause harm to humans consuming those species. In the past, individual deer have been confiscated when too close to human exposure limits. There were no confiscations in the past three years. Evidence of possible genotoxic effects from contamination was found in Pond B mallard ducks (George et al. 1991), fish (Arnett et al. 1992), and yellow-bellied pond slider turtles (Lamb et al. 1990). Slider turtles that inhabited seepage basins or other sites of known radioactive contamination also exhibited genotoxicity.

3.5 DEVELOPMENT OF CONCEPTUAL MODEL AND DATA NEEDS

Due to the size and complexity of SRS, a decision was made to concentrate on a single watershed and a single contamination source. The source selected for demonstration purposes is the old F-area seepage basin. This site is contaminated with radionuclides, heavy metals, and trichloroethylene. Contamination of groundwater beneath the basin has been confirmed; groundwater seeps and surface runoff may have entered upper Three Runs Creek. Contaminated water or sediment from the seep could have been transported to the Savannah River Swamp and the Savannah River.

Figure 5 represents the conceptual model of the upper Three Runs Creek watershed developed with the assistance of the SRS staff at the October workshop. Eight natural resources were selected for demonstration purposes: groundwater, surface water, fish, alligators, waterfowl, trees, deer, and soil. These resources were selected because (1) they are representative of the range of resources covered by the NRDA regulations, (2) there are relatively clear links to service losses for each of them, and (3) all are present within the watershed potentially affected by the old F-area seepage basin. The selection in no way implies that these resources have, in fact, been injured (or even exposed) by contaminants derived from this site.

The old F-area seepage basin itself either now contains or could potentially be habitat for most of the seven resources included in the conceptual model. Documented exposure pathways link the basin to groundwater, surface streams, and riparian wetlands within the upper Three Runs Creek

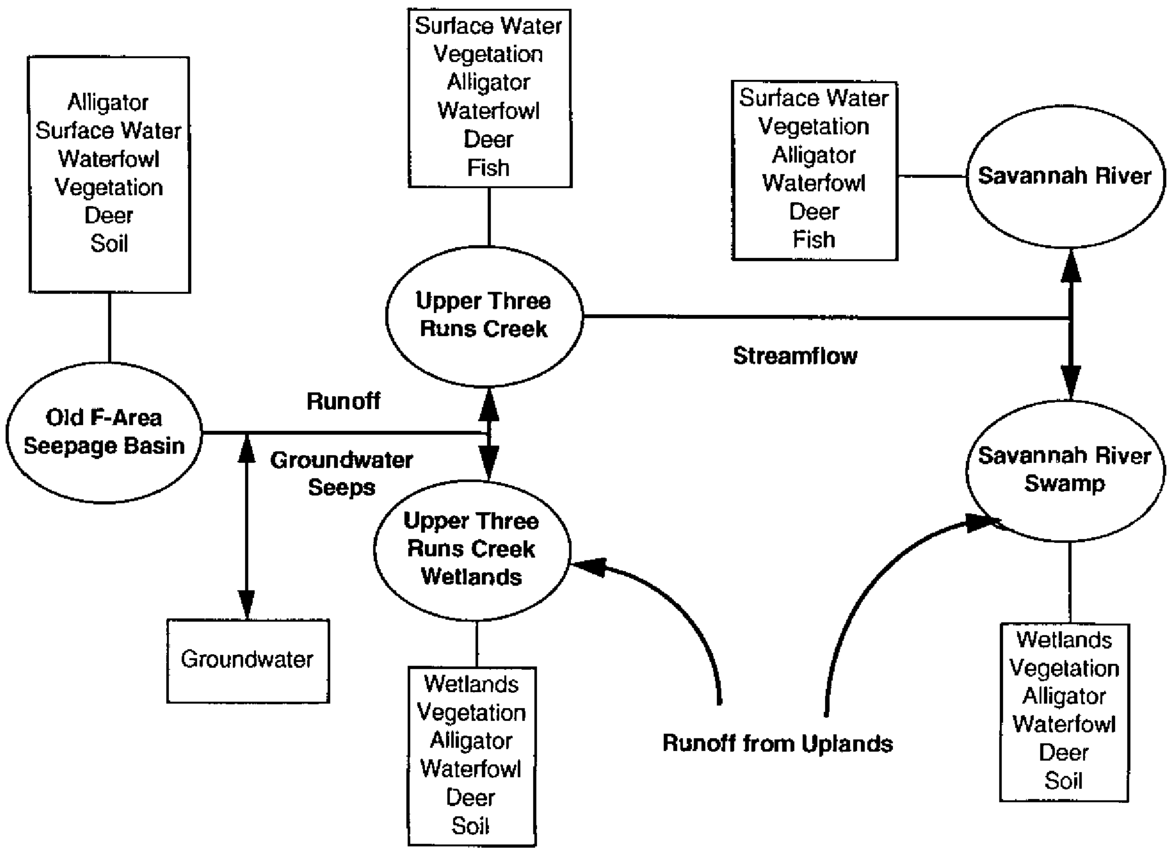

Fig. 5. Conceptual model of the upper Three Runs Creek watershed.

watershed. At the lower end of the creek, the Savannah River Swamp and the Savannah River bordering SRS provide the lower boundary of the study area. At the October workshop, participants listed the data available for the watershed that could at least, in principle, be used for NRDA purposes. OU-level studies at the basin should provide information sufficient to assess injuries to biota present in the basin and to quantify off-basin contaminant movement. Several different organizations—Westinghouse, the Savannah River Ecology Laboratory, and federal/state resource management agencies—were found to have potentially useful data on the watershed below the basin. Figure 6 summarizes these data sources. It reflects input only from the staff present at the October meeting; additional groups not present at that meeting may also have useful data.

If the integrated approach discussed in this report were actually applied to this watershed, the next step would be to examine the existing data, identify data gaps, and then develop a sampling and analysis plan to collect critical information needed to complete the injury determination. Once alternatives for restoration of the old F-area seepage basin were identified, injuries, service losses, and resulting damages would be assessed for each alternative and factored into the remedy selection process.

4. QUANTIFYING NATURAL RESOURCE SERVICES

Natural resource services are the link between natural resource injuries and the monetary damages associated with those injuries. Society places value on natural resources because they provide valuable services, such as drinking water, outdoor recreation, and the pleasure of knowing that endangered species are being preserved for future generations. When a resource is injured and the services provided by the injured resource are reduced, society suffers an economic loss. Table 2 lists services typically provided by natural resources such as the ones found on SRS.

In this section, we focus on the quantification of natural resource services. Section 4.1 presents the theoretical and conceptual aspects of natural resource service flows. Section 4.2 describes the types of data that are used by economists to estimate or measure natural resource services. Section 4.3 contains a case study using some of the services provided by the SRS natural resources and examines the data needs and potential data sources for the site.

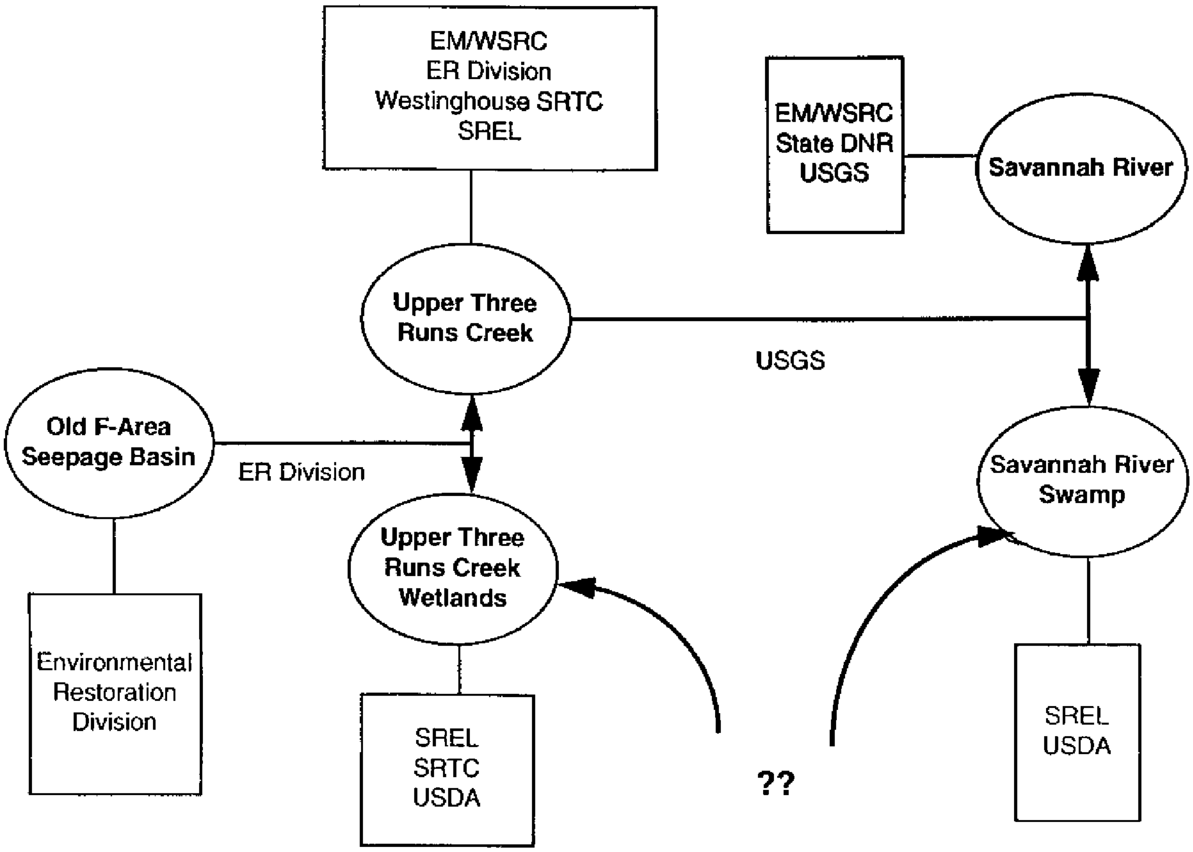

Fig. 6. Watershed information resources.

Table 2. Typical natural resource services associated with resources found on the Savannah River Site

	Surface water	Ground water	Wetlands	Terrestrial biota
Use services	Recreation Fishing Drinking water Irrigation Industrial use Scientific survey	Drinking water Irrigation Industrial use Recreation (caving) Scientific survey	Recreation Fishing Scientific survey	Timber Trapping/hunting Recreational camping, etc. Scientific survey
Nonuse services	Fish and wildlife habitat Groundwater recharge Thermal/pollutant sink	Option/bequest Filtration of water Habitat	Fish and wildlife habitat Groundwater recharge Thermal/pollutant sink Groundwater discharge Flood flow alteration Sediment stabilization Nutrient removal/transformation Production export Wildlife diversity/abundance Aquatic diversity/abundance Uniqueness or aesthetic	Ecosystem balance Genetic CO_2 sink Pollutant filtration/sink Habitat Flood control Existence value

4.1 NATURAL RESOURCE SERVICE FLOWS

The NRDA regulations (43 CFR §11.14) define natural resource services as the physical and biological functions performed by a resource, including the human uses of those functions. In general, natural resource services can be grouped into two categories: direct-use services and passive-use services. Direct-use services are services provided by resources to humans as a result of physical or visual contact with a resource. Passive-use services are services provided by a resource to humans or to other resources that do not require physical or visual contact by humans.

Figure 7 shows the flow of a natural resource service (in this case, fishing user days) and how these can be affected over time by a hazardous substance release. Prior to the release beginning in the early 1950s, the figure shows a gradual but steady increase in the annual flow of services. In the absence of a release, services often increase over time because services are typically a function of population size, which tends to increase over time. However, annual service flows may be constant, or even decline over time, depending on the particular setting.

When the release begins, annual service flows decline precipitously for several years, stabilizing at a new lower level. This lower level of services is called the with-injury service level. After the initial adjustment to the injury, the with-injury service level is shown increasing over time for the same reasons that services were increasing prior to the release. However, the with-injury service levels could also remain constant or even decline further depending on particular circumstances.

4.1.1 Baseline Service Level

The baseline service level is the level of natural resource services that would be expected in the absence of a particular release. In Fig. 8, two possible baseline service levels are shown. One baseline is the 1954 baseline. This curve represents the annual flow of services that would have occurred in the absence of the release starting in 1954. The other baseline is the 1980 baseline. This curve represents the annual flow of services that would have occurred, starting in 1980, in the absence of continuing natural resource injuries. The year 1980 is significant because that was the year Congress enacted CERCLA. In general, potentially responsible parties (PRPs) are only liable for injuries and damages that occurred wholly after the date of enactment (December 11, 1980). In such a case, the 1980 baseline would be the proper baseline for evaluating services. Under many circumstances, however, PRPs may be liable for both pre- and post-CERCLA injuries and damages, particularly where these cannot be readily distinguished. In such cases, the baseline in the year of the first release would be the proper baseline.

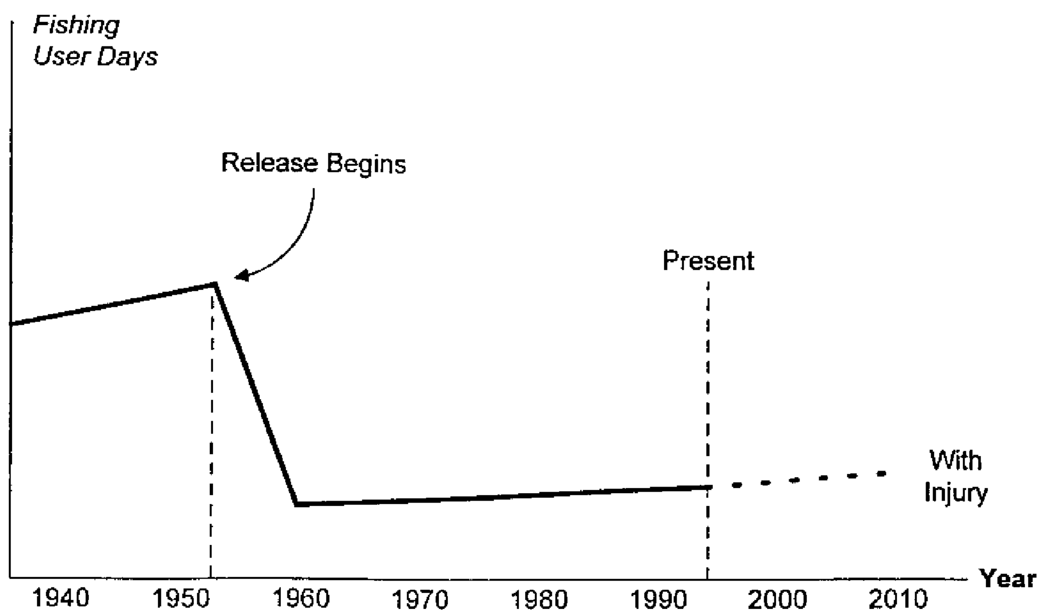

Fig. 7. With-injury service flows over time.

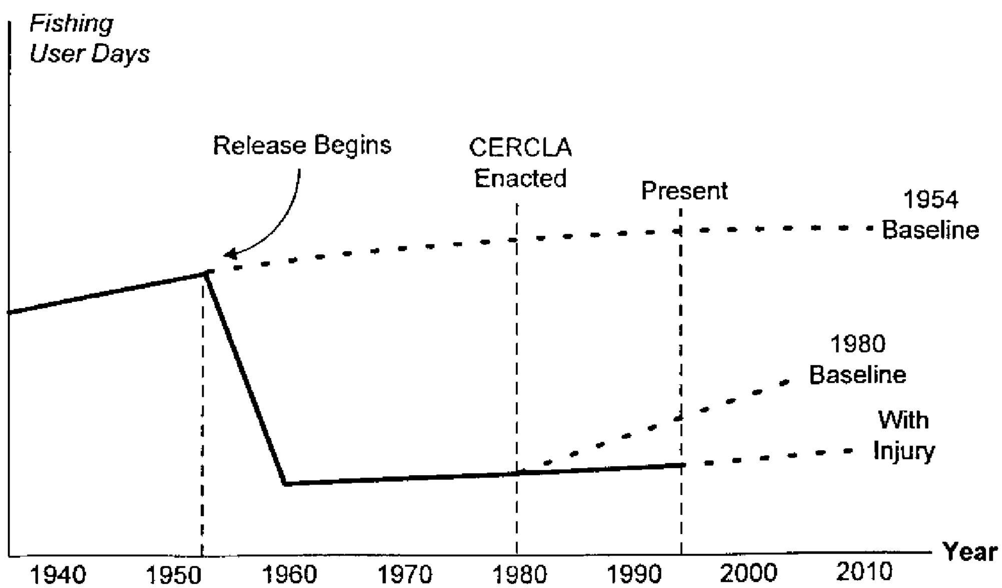

Fig. 8. Baseline service flow.

4.1.2 Forgone Services

Once the baseline level of services and the with-injury level of services are estimated, then forgone services can be estimated. Forgone services are the service losses attributable to a particular release. We can represent forgone services as the area between the baseline service level and the with-injury service level. In Fig. 9, the shaded area under the 1954 baseline represents the quantity of service losses attributable to the release beginning in 1954. The cross-hatched area under the 1980 baseline represents the quantity of service losses attributable to the release beginning in 1980.

4.1.3 Future Service Losses

Up to now we have focused on losses of services in the past. However, future service losses must also be considered because they are a potentially large source of natural resource damages. Estimating future service levels is more difficult than measuring past service levels for a variety of reasons. The most obvious reason is that both baseline and with-injury service levels must be estimated into the future, whereas with-injury service levels in the past may have been observed and measured. In addition, the service effects of remediation must be anticipated and predicted as part of future service losses.

Figure 10 is similar to the earlier service graphs in that services are plotted on the vertical axis and time is plotted on the horizontal axis, but two simplifying assumptions are made. The first is that baseline and with-injury service levels remain constant over time in the absence of remediation. The second assumption is that a 1980 baseline is the proper baseline for quantifying service losses.

4.1.3.1 Interim Service Losses

Future service losses can be divided into three chronological components. The first component of future service losses is called interim service losses. These are the service losses that occur before remediation begins. In Fig. 10, the area between the baseline service level and the with-injury service level prior to the beginning of remediation represents interim service losses. Interim service losses are largely determined by the length of time before remediation begins.

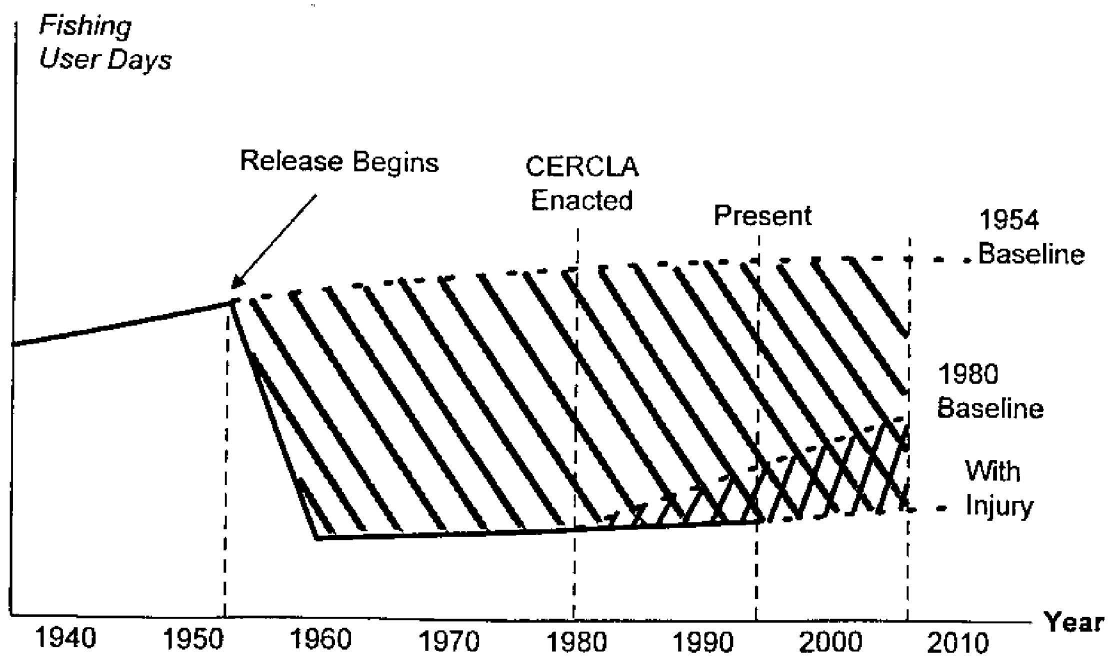

Fig. 9. Forgone services.

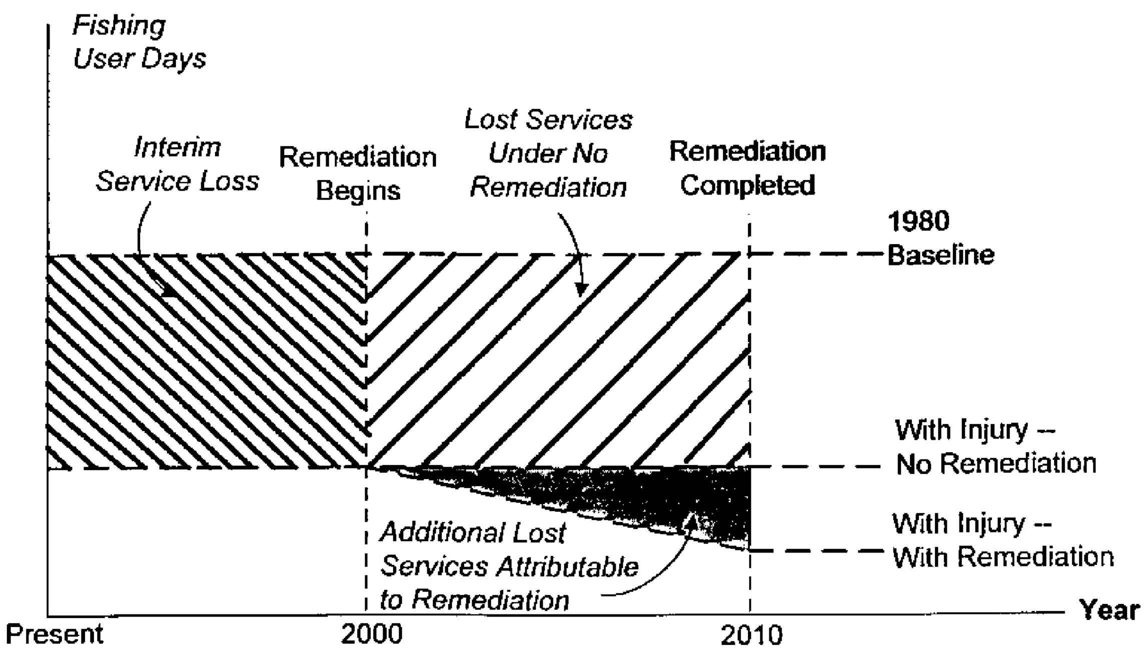

Fig. 10. Example of remediation increasing service losses.

4.1.3.2 Service Losses During Remediation

The second component of future service losses are the services lost during remediation, which are represented by the area between the baseline service level and the with-injury/with-remediation service level during remediation. The with-injury/with-remediation service curve is the level of services that occurs during remediation. Often we want to isolate the effect of remediation on lost services, so we estimate the with-injury service level in the absence of remediation. The area between the with-injury/no-remediation curve and the baseline curve during remediation represents the services that would be lost during this time period if remediation did not occur (Fig. 10). The difference between the no-remediation lost services and the with-remediation lost services is the lost services attributable to remediation. In Figure 10, remediation leads to a decline in the with-injury service level and a consequent increase in lost natural resource services, which is represented by the shaded triangle. As a result, this remediation scenario increases natural resource damages.

Figure 11 shows a remediation scenario that leads to a decrease in lost services. During remediation, the with-injury/with-remediation service level increases above the with-injury/no-remediation service level, resulting in a decline in lost services. The shaded triangle represents the reduction in natural resource services resulting from this remediation action.

4.1.3.3 Postremediation Service Losses

The third component of future service losses is postremediation service losses. Following remediation, the with-injury service level often remains below the baseline service level, resulting in additional lost services.

In Fig. 12, we assume a linear natural recovery requiring about 27 years following remediation. For simplicity, we assume that the with-injury service level remains constant throughout remediation. The postremediation service losses are represented by the shaded triangle. The magnitude of the postremediation service losses is partly a function of the service level resulting from remediation, and partly a function of the length of time required for the with-injury service level to return to baseline. The lower the with-injury service level following remediation, the larger the postremediation service losses, other things being equal. Similarly, the longer it takes the with-injury service level to return to the baseline service level, the greater are the postremediation service losses.

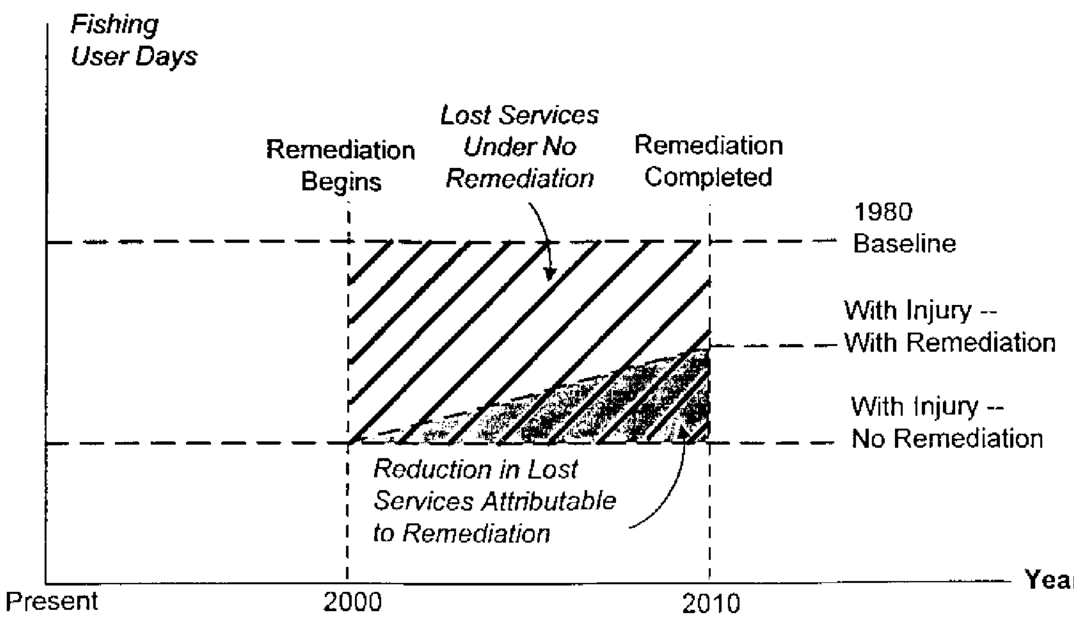

Fig. 11. Example of remediation decreasing service losses.

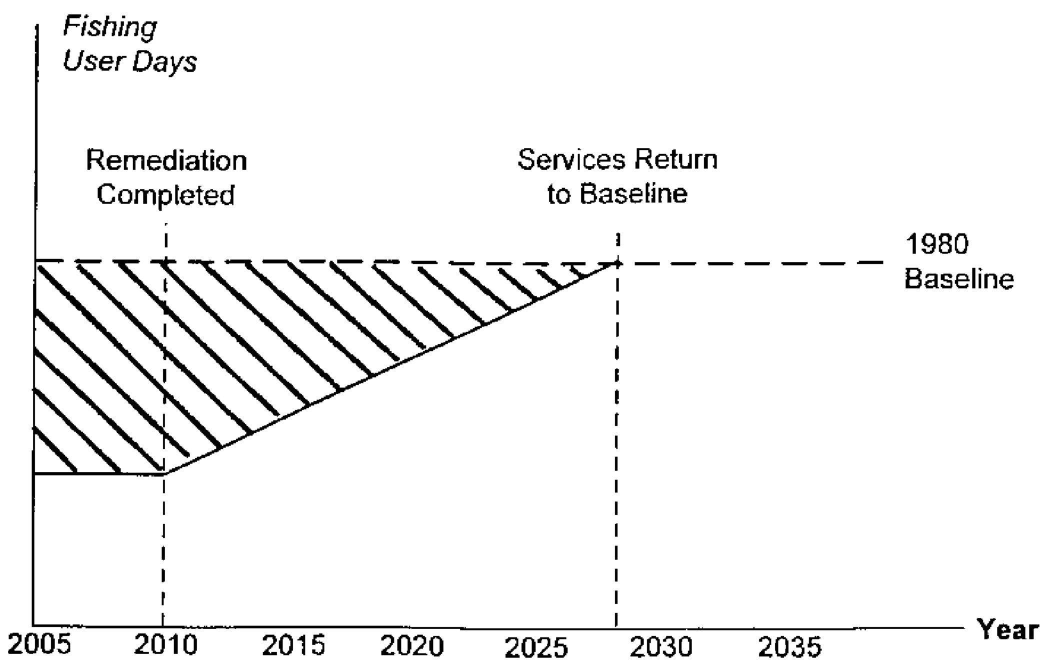

Fig. 12. Example of natural recovery following remediation.

In cases where the resources are injured severely, services may never return to baseline naturally. Figure 13 shows foregone postremediation services when the with-injury service level remains below the baseline service level. Under this scenario, postremediation service losses continue indefinitely into the future.

Since postremediation service losses may be large, PRPs benefit when the with-injury service level returns to baseline more quickly than under natural recovery. Consequently, PRPs often initiate activities that are collectively called restoration. Restoration is any action undertaken to accelerate the return of the with-injury service level to baseline. As a result, we must anticipate restoration activities and predict the resulting service effect in order to estimate total future service losses.

Figure 14 shows the service effects associated with restoration undertaken following remediation.[2] The dotted line is the path services would follow in returning to baseline under natural recovery. The path services would follow in returning to baseline under restoration is shown above the natural recovery service path. The shaded area between these curves represents the reduction in lost services attributable to restoration.

Sometimes, however, services do not respond immediately to restoration activities as depicted in Fig. 14. In particular, services may not increase above the natural recovery level for some time following the start of restoration activities.

In Fig. 15, restoration begins immediately following the completion of remediation. However, services remain at the natural recovery level for a while after restoration begins and then eventually respond to the restoration activities. An example of services not responding immediately to restoration activities would be the replanting of hardwood forests. Following the planting of the trees, it takes many years before the forest is mature and can supply the services typical of a hardwood forest. Under these conditions it becomes more difficult to estimate the future service losses because of the long time frame into the future.

4.2 MEASURING SERVICES

The previous section dealt entirely with conceptual representation of natural resource service flows. This section focuses on the data used to actually measure services. The data sources for

[2] Restoration does not have to follow remediation; restoration can be initiated at any time. We assume that restoration follows remediation for simplicity.

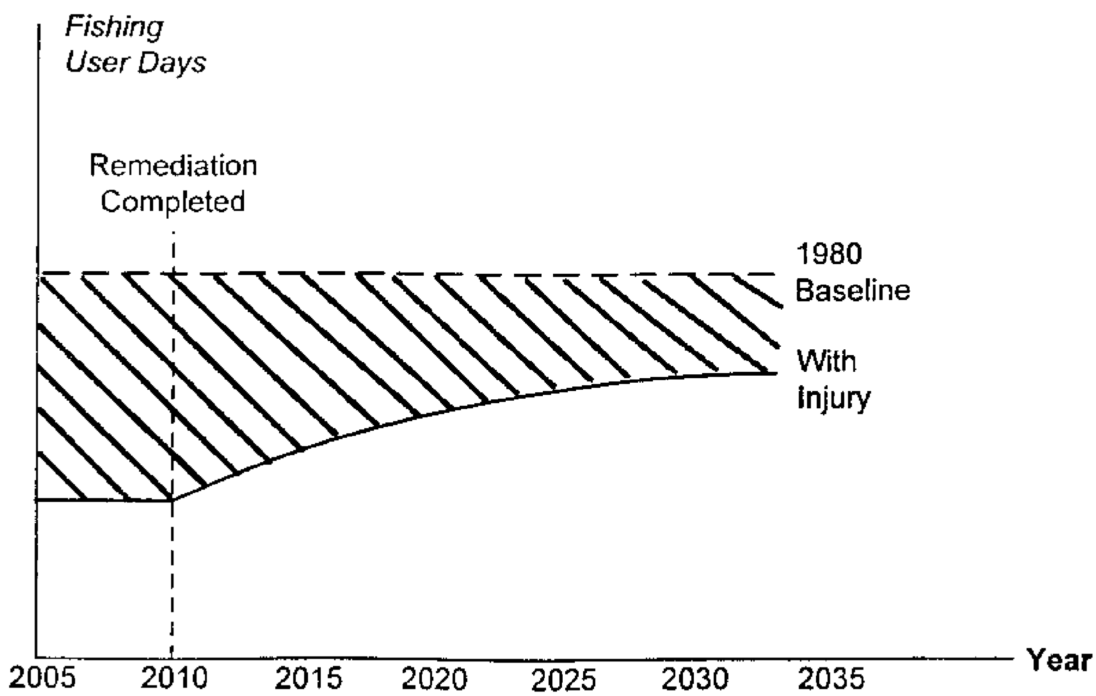

Fig. 13. Example of natural recovery not occurring.

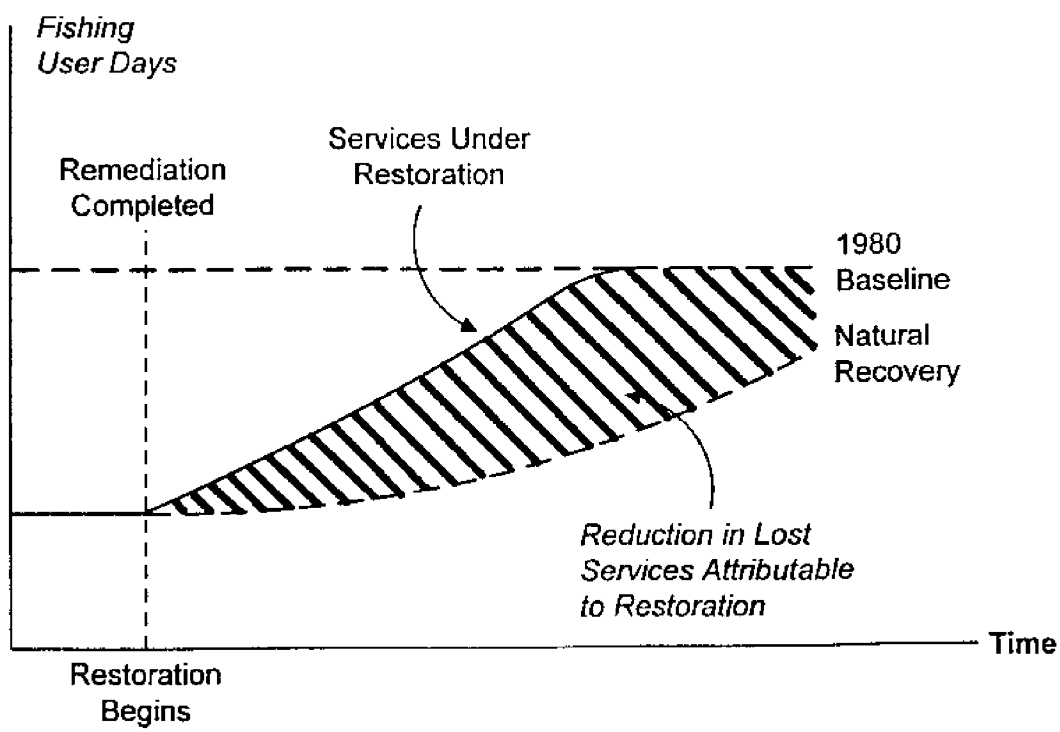

Fig. 14. Example of restoration with immediate results.

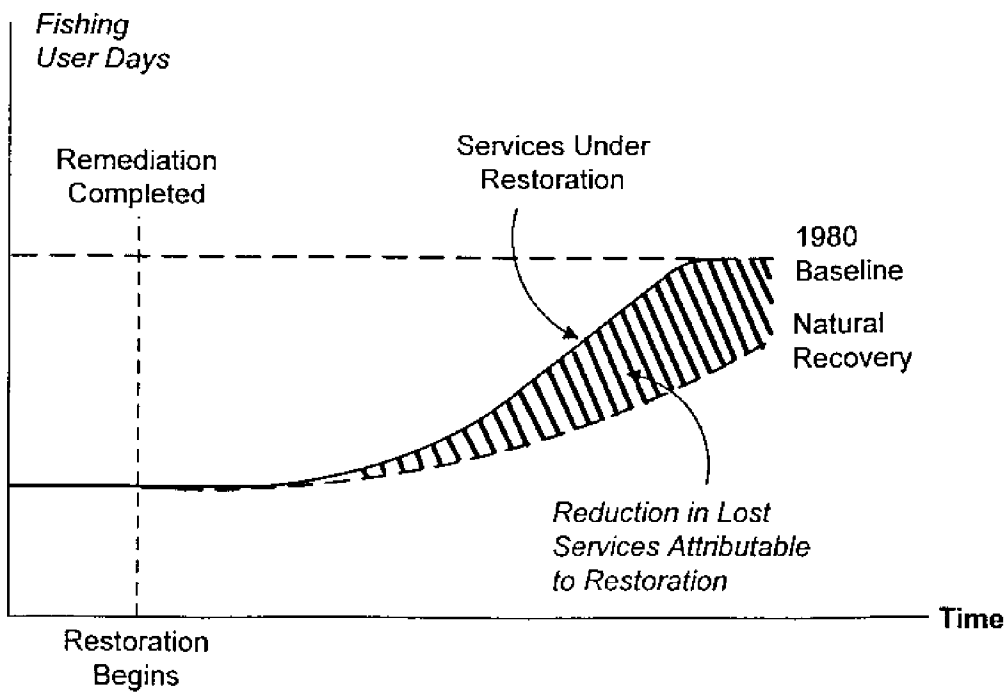

Fig. 15. Example of restoration with delayed results.

estimating direct-use services are distinguished from the data sources for estimating passive-use services because direct-use services deal mostly with human activities and passive-use services deal exclusively with ecological conditions and/or human perceptions.

4.2.1 Data Sources for Measuring Direct-Use Services

There are a variety of data sources for estimating direct-use services. Examples of some types of data that can be used to measure direct-use services include

- participation rates, visitation rates, and timber harvest rates;
- surveys asking people about their current activities;
- estimates of future conditions by "experts"; and
- creel surveys, past studies of visitation rates, and license data.

The first group contains types of data that are typically available in public documents. For example, most states publish reports that list the average number of times people in particular regions participate in certain recreation activities such as fishing. Participation rates are useful in estimating the total number of recreation trips that are taken annually by a particular group of people. Visitation data from state and federal parks are useful in estimating the number of people who use a particular area. Timber harvest rates are important for measuring the potential commercial value of some forest resources. Using these types of data, the current level of direct-use services provided by a resource can be measured, and future service levels can be estimated.

When public data are insufficient, or more detailed data about a specific resource or activity are needed, survey data can be used in estimating service levels. Often, existing survey data can be reviewed and used to measure services. For example, surveys completed by visitors at a state park may be useful in estimating the relevant geographic market for the services provided by the resources at the park.

When existing survey data are insufficient, new surveys on natural resource services may be designed and conducted. Often these surveys are conducted in such a way that respondents provide information about their recreational activities. For example, some surveys recruit people to participate in longer in-depth surveys in which the respondents keep a detailed log of their recreational activities.

Estimates of current and future service levels by “experts” may be very useful in measuring natural resource services. For example, local fishing guides may be asked to estimate the number of anglers that fish in a particular area. Another example is that marina operators may be asked to estimate the number of people who use their boat launch daily.

Other types of data may also be useful for measuring historical service levels. Measuring historical services lacks some of the uncertainty involved in estimating future service levels, because data often consist of actual observations of past conditions. For instance, we do not have to rely on an “expert” opinion to estimate past visitation at a park. We can simply use the actual park attendance records. Creel studies are often used because they contain documented data characterizing past fishing conditions. Similarly, license data provide an actual measure of the number of people who went fishing.

4.2.2 Data Sources for Measuring Passive-Use Services

There are a variety of data sources for measuring passive-use services. Usually, data that characterize the ecological conditions of a resource are required for measuring passive-use services. Below are some of the types of data that can be used to measure passive-use services:

- existing biota conditions, population estimates, and groundwater conditions;
- scientific documentation of the expected contaminant effects on biota and groundwater; and
- "expert" estimates of future and past conditions.

The first group contains types of data that characterize the actual ecological conditions of a resource. These data are useful for understanding the services associated with the resources and identifying what injuries have occurred as a result of a release. In addition to these types of ecological survey data, ecological studies that document contaminant effects on biota and groundwater are very useful for measuring passive-use services. Finally, “experts” who can provide estimates of future biota and groundwater conditions are sought. For example, a study of groundwater contamination may be used to estimate the likely effects of certain releases. Based on the anticipated effect, an “expert” may be asked to predict the future groundwater conditions at a particular site. Similarly, “experts” may provide estimates of past ecological conditions, when data are not available.

4.2.3 Data Sources for Estimating Baseline Services

Several techniques can be used to estimate baseline service levels. The first technique is the use of a control area. A control area is an uninjured part of a partially injured resource. For example, an upstream reach of river is often a useful control area for an injured downstream reach of the river. The ecological conditions of the control area are compared to the ecological conditions of the injured area. The assumption is made that the only differences in the two areas is that the control area has not been affected by the release that injured the downstream site. Therefore, one can assume that the ecological differences in the two areas are attributable to the release and injury at the downstream site.

In a similar manner, reference areas are sometimes used instead of control areas. A reference area is a resource that is as similar as possible to an injured resource except the reference area has not been injured by a release. Just as with control areas, the ecological conditions of both areas are compared and the differences are attributed to the release that injured the affected area.

When suitable control or reference areas cannot be found or are inappropriate, other techniques can be employed. One technique is to consult “experts.” Often “experts” can review data that characterize current ecological conditions and estimate baseline service levels relative to current with-injury service levels. Another technique is to review ecological studies that have documented the service effects in a setting similar to the case in question. If the likely effects of the release can be identified and current ecological conditions are known, the baseline service level can be estimated.

4.3 DATA NEEDS FOR SERVICE QUANTIFICATION FOR SRS

As noted earlier, the old F-area seepage basin at SRS was selected for a natural resources services case study. Four types of services were selected for an exercise in identifying potential data sources for quantifying services at the old F-area seepage basin. The four categories of services are

- direct-use services provided by trees,
- direct-use services provided by fish,
- passive-use services provided by alligators, and

- passive-use services provided by groundwater.

These resources are both representative of what are found at SRS and allow illustration of the handling of the major types of resources of concern. Since trees are harvested for timber at SRS, trees were selected to represent resources that provide a commercial service. Fish were selected to represent resources that provide direct-use recreational services. Alligators are a threatened species in much of the southeast and were selected to represent threatened and endangered species that might provide passive-use services. Lastly, groundwater was selected to represent nonbiological resources that might provide passive-use services.

For each resource and associated service type, we identify the primary data needs, give relevant background information, and identify potential sources for needed data. The background information and sources for data are not intended to be an exhaustive listing, but merely an example of the types of data that are relevant.

4.3.1 Direct-Use Service Quantification for Trees

4.3.1.1 Data Needs

The following types of data are needed to quantify the direct-use services provided by trees:

- acres of trees, by type, that have been injured downslope from the site;
- acres, if any, of injured trees that have the potential to be harvested;
- board feet of lumber/acre that could be harvested from these injured trees, by type; and
- board feet of lumber/acre that could be harvested from these injured trees, by type, in the absence of injuries.

4.3.1.2 Background Information

The following background information is available on trees in the old F-area seepage basin at SRS:

- Using dendrochronological procedures, researchers have concluded that contaminants from the old F-area seepage basin have injured trees.

- Trees downslope from the site, growing in groundwater seeps, have experienced decreased resistance to drought stress, leading to increased mortality and decreased growth.

- The majority of injured trees are swamp tupelo; however, injury has been observed in sweetgum, tulip poplar, loblolly pine, and several species of oak.

- SRS is divided into forestry management units called timber compartments. Compartment 49 contains the old F-area seepage basin. The surrounding compartments that may be affected are 50, 65, and 67.

- Every 10 years, a forester examines each compartment and prepares a detailed prescription recommending cuts and silvicultural treatments.

- The SRP Timber Management Plan restricts bottomland hardwood harvest to 400 acres annually; however, usually less than 100 acres are harvested. In some years no bottomland hardwood timber is harvested.

- In FY 1985, two 50-acre tracts of bottomland hardwood were harvested from the upper Three Runs Creek (UTRC) flood plain.

4.3.1.3 Potential Sources for Needed Data

The following are potential sources of information on trees in the case study area:

- timber compartment prescriptions for the potentially affected areas,

- data from the FY 1985 timber harvest along the UTRC flood plain,

- more studies on potential injuries to trees from groundwater contamination, and

- data from timber harvests on tracts similar to those potentially injured downslope from the site.

4.3.2 Direct-Use Service Quantification for Fish

4.3.2.1 Data Needs

The following types of data are needed to quantify the direct-use services provided by ash:

- current and historical magnitude of annual fish injuries in the Savannah River adjacent to and downstream of SRS;

- effects of injuries on total biomass (e.g., reduction in average weight, reduction in population, redistribution between species);

- comparisons of biomass conditions in the Savannah River adjacent to and downstream of SRS with biomass conditions in the Savannah River upstream of the site and in comparable rivers;

- magnitude of the injuries, if any, to fish in the Savannah River attributable to releases from the Old F-Area Seepage Basin; and

- the relationship between biomass and fishing activity.

4.3.2.2 Background Information

- Annually, fish samples are collected from the Savannah River and tested for the presence of radionuclides.

- Fish collected upstream in Lake Thurmond are used as control samples.

- Fish sampled in the Savannah River adjacent to and downstream of the site contain measurable quantities of gross alpha radionuclides, nonvolatile beta radionuclides, and gamma-emitting radionuclides.

- The old F-area seepage basin is a potential source of gross alpha and nonvolatile beta radionuclides.

- A study by Loehle and Paller (1990) concludes that liquid wastes from old F-area seepage basin that have seeped into wetlands along Four Mile Creek have not lead to any significant or measurable injury to fish in Four Mile Creek.

- A detailed environmental assessment of the old F-area seepage basin has been completed that, among other things, models the chemical transport for several pathways including groundwater outcropping and the resulting ecological effects.

- The 1988 Savannah River creel study, conducted by Georgia Department of Natural Resources, monitored sportfishing activity along the entire reach of the Savannah River for one year (Schmitt 1989).

4.3.2.3 Potential Sources for Needed Data

- the 1988 Savannah River creel study;

- a similar creel study for a similar river, preferably in Georgia;

- data from annual fish sampling in Savannah River by SRS staff;

- studies identifying the potential for contaminants from the old F-area seepage basin entering nearby streams and flowing into the river;

- studies identifying the most likely sources of radionuclides in the Savannah River fish; and

- studies identifying any other injuries to fish in the Savannah River that may be attributable to SRS operations.

4.3.3 Passive-Use Service Quantification for Alligators

4.3.3.1 Data Needs

- the current and historical magnitude of injuries, if any, to alligators downstream from the site;

- the effects of injuries on alligator biomass (e.g., reduction in population, reduction in size);

- the sources of contaminant(s) causing injuries to alligators and the portion of injuries attributable to releases from the old F-area seepage basin; and

- a comparison of alligator biomass conditions at similar reference areas.

4.3.3.2 Background Information

Background information on alligators in the old F-area seepage basin includes the following:

- According to Murphy (1981), UTRC below the old F-area seepage basin has only marginal alligator habitat, and only limited alligator activity would be expected.

- Murphy (1981) provides detailed information about the alligator population structure in Par Pond, which may be useful in estimating the baseline alligator population downstream of the site.

4.3.3.3 Potential Sources for Needed Data

- studies linking injuries to alligators with contaminants released on-site and

- the environmental assessment of old F-area seepage basin, which provides information on the likelihood of contaminants from the area reaching downstream alligator populations.

4.3.4 Passive-Use Service Quantification for Groundwater

4.3.4.1 Data Needs

Data needed for quantification of groundwater passive-use services include the following:

- the quantity of injured groundwater, currently and historically, and

- the services normally provided by this injured groundwater.

4.3.4.2 Background Information

- The old F-area seepage basin is identified as one of 33 sources of groundwater contamination at SRS.

- Groundwater is extensively tested for the presence of radionuclides and chemicals in about 576 wells.

- Groundwater testing data are usually summarized in an annual report titled “Savannah River Plant, Environmental Report.”

- Most contaminated groundwater occurs in shallow aquifers, which typically drain into downslope surface water via springs and seeps. However, there is the potential that shallow contaminated groundwater can migrate downward into larger deep aquifers.

4.3.4.3 Potential Sources for Needed Data

- the old F-area seepage basin on-site well monitoring data and

- water monitoring data from down-gradient outcroppings and seeps.

4.4 SUMMARY OF SERVICE QUANTIFICATION CONCLUSIONS

Natural resource services are best depicted as service flows over time as in Fig. 7. When a natural resource injury occurs, the flow of services from a resource declines or stops altogether. Often, the flow of services from an injured resource slowly increases as the injured resource returns to normal. The path services follow from the time of the injury until the resource has fully recovered determines the reduction in services as a result of the injury. Therefore, it is important to estimate the path services follow during a resource injury and recovery in order to estimate the quantity of lost services.

Conceptually, measuring services over time is easily accomplished. However, in actuality, the task is more arduous because of the extensive data needs associated with measuring services. Many sources of data, such as public reports, surveys, and “expert” opinions, can be used to measure services. However, it is hard to generalize about data needs because each resource and injury is unique, requiring an individualized approach. We have illustrated identifying data needs and potential data sources for measuring services for selected resources at SRS. This task demonstrated how the data needs for measuring services vary by resource, even for resources at the same site.

5. DAMAGE DETERMINATION

Determining natural resource damages is a complex task because there are a variety of factors that must be addressed. First, the per unit value of the resource services must be estimated. Economists can sometimes use a market approach to estimate the value of resource products, but for most resources, a nonmarket approach, where the value of the resource is determined by unit of use, such as per fishing trip, must be used. Some resources do not provide any direct-use services and, therefore, can only be valued in a hypothetical setting.

Once the resource is valued, the value of the lost services over time can be calculated. Measuring the value of lost services over time presents some difficulty because the service effects of restoration must be considered. Another complicating factor is the effect of time on values. All damages must be estimated in their net present value, so the timing of future restoration activities becomes an important determinant of damages. Once the expected restoration action is decided and the future damages are calculated, the present value of all past damages is added to the present value of all future damages to arrive at total damages.

5.1 VALUING LOST DIRECT-USE SERVICES

Methods for valuing lost direct-use services usually fall into one of these categories: market value, appraised value, or nonmarket value (consumer surplus).

Market value and appraised value approaches to valuing natural resource services rely on market-based data. For example, assume that the federal government owned a large tract of farmland in a farming region. Let's also assume that the government's land was severely injured by a hazardous release and was no longer arable. The value of the lost services associated with the resource injury could be determined using either of these approaches. For example, if the government sold the injured land, the market price of the injured land could be compared to the market value of similar land. The difference in the values would equal the value of the lost services resulting from the injury, all other things being equal. If the government does not sell the land, an appraiser could still estimate the current market value (appraised value) of the land. The difference in the appraised value and the market value for similar land would equal the value of the lost services resulting from the injury, all other things being equal.

Unfortunately, most natural resources are not traded in a market. Therefore, few, if any, market data exist for valuing natural resource services in the NRDA setting. Since these market-based approaches have such restrictive applicability in the natural resource area, economists must use nonmarket approaches. Nonmarket valuation approaches are used to estimate the reduction in consumer surplus associated with a particular resource injury. Consumer surplus is defined as the maximum willingness to pay (WTP) for using a resource minus the total expenditure associated with using the resource. For a given resource, the average consumer surplus per trip is estimated and multiplied by the number of trips, to arrive at the total consumer surplus associated with the resource.

For example, assume that a hiker routinely pays $25 in travel expenses to hike in a national forest. However, the hiker would be willing to pay as much as $40 to hike in that national forest. In this case, his consumer surplus for a hiking trip in this national forest would equal $15 ($40–$25). Natural resource damages are supposed to equal the monetary value needed to compensate society for the natural resource service losses resulting from a hazardous substance release. In theory, the monetary compensation to society should be just enough to make society as well off as without the release. Since consumer surplus is a measure of the value people place on the services they receive from natural resources, the reduction in consumer surplus associated with a particular release satisfies the requirement for natural resource damages.

There are four methods for estimating consumer surplus: (1) the travel cost model (TCM); (2) the random utility model (RUM); (3) contingent valuation method (CVM); and (4) values from past studies (transfer).

TCM is a widely used method for estimating the recreational benefits of natural resources. The logic underlying TCM is simple. Recreationists at a particular site pay an “implicit” price for using the site’s services through the travel and time costs associated with visiting the site. Because recreationists from diverse origins visit a site, their “travel behavior” can be used to analyze the demand for the site’s services. Once the demand curve for the site’s services has been determined, the consumer surplus associated with the site can be estimated by subtracting travel costs from the area under the demand curve, which reflects maximum willingness to pay.

TCMs are usually estimated by surveying users at a specific recreation site. Collected data includes distance traveled, trip expenditures, and duration of trip. However, since data are only collected from one site, TCM cannot properly account for sites that have a large number of substitute sites. Because of this inability to account for substitutes, many economists are now using RUMs to estimate consumer surplus. RUMs are able to deal effectively with the problems associated with valuing a resource that has many substitutes. RUM is a state-of-the-art TCM based on a utility-theoretic method of examining peoples’ recreation decisions. RUMs predict the probability that an individual taking a recreation trip will select a particular site, or resource, from a relevant "choice-set." RUMs incorporate advanced statistical techniques to estimate this probability as a function of travel cost and site characteristics. The utility of a particular site, or resource, is determined from the probability distribution associated with all of the relevant sites. A resource's utility is converted into a WTP value from which economists estimate the consumer surplus associated with a resource.

The third method of estimating consumer surplus losses is the contingent valuation model (CVM). CVM involves surveying individuals to elicit their WTP for different levels of natural resource services. For example, a CVM survey may describe an actual or hypothetical resource injury resulting in an actual or hypothetical service loss. After describing the service loss, the survey asks respondents to state their maximum WTP to avoid the service loss. The consumer surplus they receive from the services provided by the resource is determined by subtracting their cost of using the resource from their maximum WTP.

A fourth method of estimating consumer surplus is to use values from past studies of the same resource or to transfer values from studies of other resources. This method is straightforward in that consumer surplus estimates from studies of similar resources are used to estimate the reduction in consumer surplus associated with a current resource injury. For example, a valuation study of trout fishing in Colorado may be useful in valuing the service losses associated with an injury to a trout stream in neighboring Wyoming. Specifically, consumer surplus estimates from the original study can be adjusted to approximate the consumer surplus associated with the injured resource. Valuation studies are regularly published in resource economics journals.

5.2 VALUING LOST PASSIVE-USE SERVICES

Passive-use values are values not linked to direct uses of a natural resource, including the following:

- the value of knowing that others can use the resource,
- the value of protecting the resource for its own sake, or
- the value of knowing that future generations can use the resource.

Since passive-use services are not traded in a market, the only measure of passive-use values is consumer surplus. The only method for valuing passive-use services is the CVM. People are surveyed and asked to state their maximum WTP to avoid a particular loss in passive-use services.

These WTP values are the reduction in consumer surplus associated with the passive-use service loss since the survey participants incur no costs associated with these services.

However, CVM estimates of passive-use values are much less reliable than CVM estimates of direct-use values because people find it more difficult to value passive-use services than direct-use services. In 1992, the National Oceanic and Atmospheric Administration (NOAA) commissioned a "blue ribbon" panel, including two Nobel prize-winning economists, to evaluate the reliability of CVM passive-use value estimates. The NOAA panel had numerous concerns including the following:

- respondents' hypothetical WTP values overstate their actual WTP;
- CV responses are often inconsistent with rational choices;
- CV responses are often implausibly large;
- the CV framework suffers from the lack of a meaningful budget constraint;
- many CV surveys provide inadequate information and lack of acceptance by the respondents;
- CV studies have difficulty in determining who to survey; and
- some CV WTP estimates are measuring "warm glow" values for a particular resource or for the environment in general, instead of values associated with the service loss (58 Federal Register 4603–4605, Jan. 15, 1993).

The NOAA panel concluded that under certain circumstances, where these and other concerns are addressed, CVM estimates of passive-use values may be useful in determining passive-use damages.

In addition to the concerns of the NOAA panel, many economists have other concerns. One concern is that CVM survey respondents may overstate their actual WTP by considering punitive damages and not just compensatory damages related to the service loss. Another concern is that CVM studies may induce values from people who are often unfamiliar with the resource and/or injury in question and, therefore, cannot properly value the service loss. Many economists also question whether temporary injuries to common resources produce a loss in passive-use values. Finally, CVM estimates are often not robust in that the WTP estimates are sensitive to changes in the survey format, model specification, and statistical techniques employed in the study.

5.3 SPECIFIC EXAMPLES FROM OLD F-AREA SEEPAGE BASIN

Using the old F-area seepage basin example, four natural resource services were selected for our examples of valuing services. Assume that a release has occurred at the site and the following services have been reduced:

- commercial timber services of trees,
- angling services provided by fish,
- passive-use services provided by alligators, and
- passive-use services associated with groundwater.

Since timber is traded or sold in a market, a market value approach could be used to value the loss of services provided by timber. First, the per unit market value of timber would be determined using timber market data such as sales receipts. Next, the per unit value of timber would be multiplied by the quantity of timber that was lost because of injury. This product would equal the value of the lost direct-use services provided by commercially harvested trees near the old F-area seepage basin, which will be the basis for the natural resource damages.

Since fish in this reach of the Savannah River are not commercially harvested, a market-based approach could not be used to value lost angling services. Instead, a nonmarket approach would be required to estimate the consumer surplus associated with fishing. First, using a nonmarket valuation method such as a RUM, the consumer surplus per user day would be calculated. Next the value of a user day would be multiplied by the number of user days that had been lost as a result of releases from the old F-area seepage basin. This product would equal the value of the lost angling days and would serve as the basis for natural resource damages.

For both alligators and groundwater, there are no associated direct-use services at this site; therefore, potential service losses would come from a decline in passive-use services. A nonmarket approach would be required to estimate the reduction in consumer surplus resulting from a decline in passive-use services. The only possible valuation method would be a CVM study. Using a CVM survey, the average consumer surplus per household for the passive use services provided by alligators and groundwater would be estimated. Based on the estimated consumer surplus and the estimated decline in services, the reduction in consumer surplus attributable to the decline in passive-use services would be estimated. The estimated decline in consumer surplus would constitute the natural resource damages associated with the decline in services provided by alligators and groundwater.

5.4 ESTIMATING TOTAL DAMAGES

Total damages equal the sum of restoration costs, compensable value, and assessment costs. Restoration costs are the engineering, operation and maintenance costs associated with returning natural resource services to baseline levels sooner than natural recovery. Suppose a hazardous substance release kills the fish in a stream. Restoration costs would include the cost of restocking the stream with fish in order to restore fishing services sooner than natural recovery. Compensable value is the value of the lost fishing services prior to the restoration of fishing services to baseline. Assessment costs are the costs associated with determining restoration costs and compensable value.

To estimate total damages, the future compensable values and restoration costs must be predicted, both of which are a function of the restoration alternative selected. Compensable value and restoration costs are usually inversely related. As restoration alternatives become more intensive the costs increase, yet at the same time services return to baseline more quickly, reducing lost services and reducing compensable value. This trade-off between increased restoration costs (cost) and decreased compensable value (benefit) should be analyzed in order to minimize total damages.

Table 3 presents an example of this trade-off. All three restoration alternatives have the same cost in this hypothetical example. However, Alternative A reduces compensable values the most, followed by Alternative C, and then Alternative B. Overall, Alternative A reduces natural resource damages by $10 million. Alternative C has no effect on natural resource damages, because its reduction in compensable values is the same as its cost. Finally, Alternative B actually increases natural resource damages, because its costs are greater than the resulting reduction in compensable values.

Table 3. Hypothetical example of the effect of various restoration alternatives on natural resource damages

	Restoration alternatives		
	A ($\$10^6$)	B ($\$10^6$)	C ($\$10^6$)
Restoration costs	10	10	10
Change in compensable value	-20	-5	-10
Net effect of restoration on natural resource damages	-10	+5	0

5.5 SELECTING RESTORATION ALTERNATIVES

DOI lists ten factors that trustees should consider when selecting restoration alternatives. These ten factors are

1. technical feasibility,
2. relationship of expected costs to expected benefits,
3. cost-effectiveness,
4. results of response actions,
5. potential for additional injury resulting from restoration actions,
6. natural recovery period,
7. ability of the resource to recover with or without alternative actions,
8. acquisition of equivalent land when restoration, rehabilitation, or replacement are not possible,
9. potential effects on human health and safety, and
10. consistency with applicable laws and policies (59 Federal Register 14285, Mar. 15, 1994).

The DOI regulations do not prioritize these criteria, nor do they require the trustees to comply with any of them.

In order to minimize total natural resource damages, while taking into account DOI's ten criteria, we recommend the following procedure for selecting restoration actions at DOE sites:

1. Identify "relevant" restoration alternatives, which are both technically feasible (DOI Factor 1) and consistent with applicable laws and policies (DOI Factor 10).

2. Of these "relevant" alternatives, select the most cost-effective alternative (DOI Factor 3) or the alternative providing the greatest net benefit (DOI Factor 2), taking into account the remaining six factors.

The flowchart below (Fig. 16) outlines the steps that we recommend be taken at DOE sites in determining damages.

5.6 INFLUENCE OF TIMING ON DAMAGES

The DOI regulations state that damages occurring in different years must be converted to their net present value before they are summed. Equal dollar amounts paid or received in different years do not have the same present value, because of the time value of money. For example, if a person were to have a choice between receiving \$100 today or \$100 five years from now, the person should choose to receive the money today, because the present value of the \$100 five years from now would be less than the present value of \$100 today. Similarly, the present value of \$100 received five years ago is greater than \$100 today, because the money could have been invested, yielding more than \$100 today.

The process of converting future values into their present value is known as discounting. The formula for discounting is:

$$PV = \frac{V_t}{(1+r)^t}$$

where

PV	=	the present value,
V_t	=	the dollar amount received or paid t years into the future,
r	=	the discount rate.

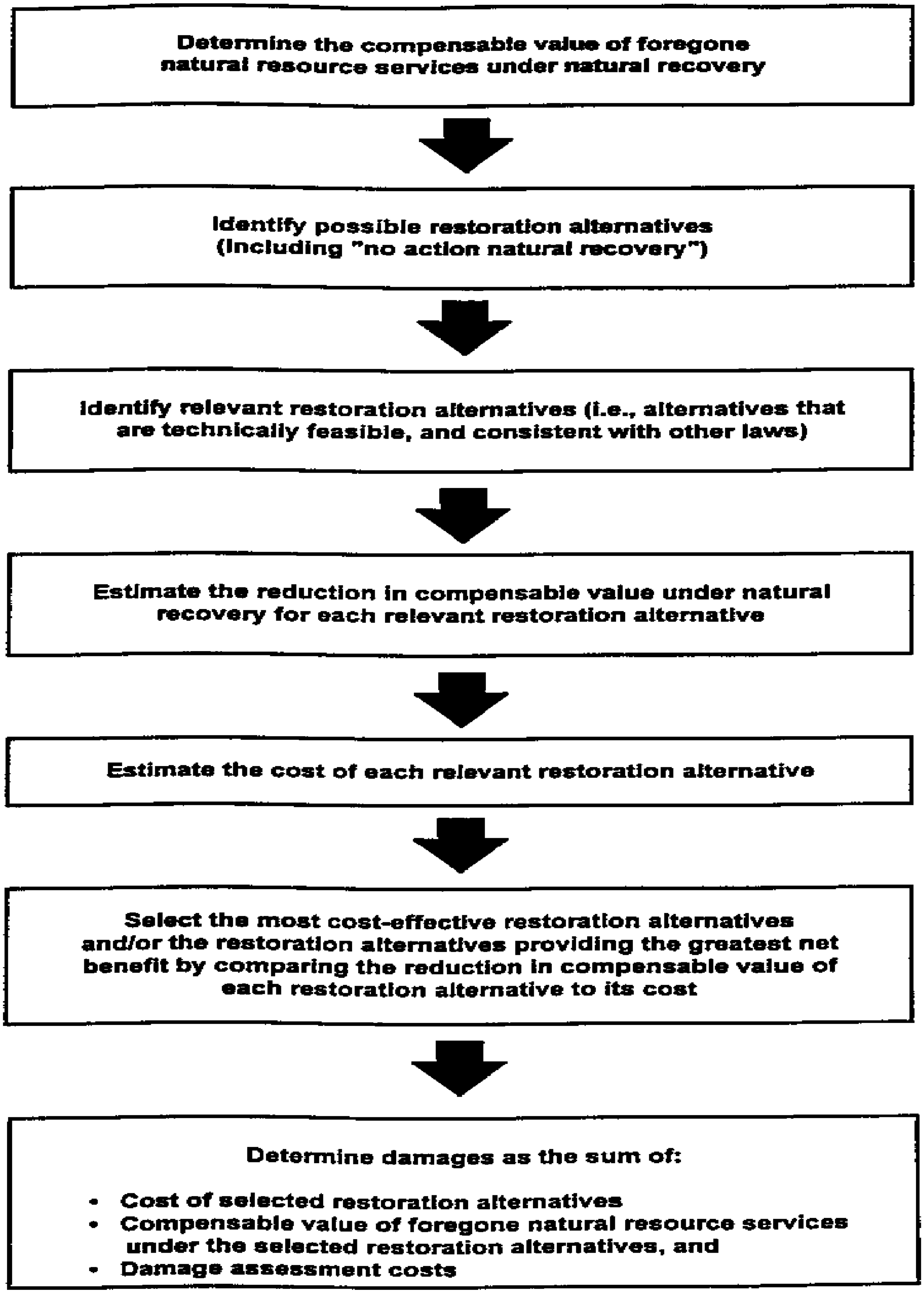

Fig. 16. Recommended steps in damage determination at Department of Energy sites.

Using this formula, it is evident that future values have a smaller present value, because the value in the future year (i.e., V_t) is divided by a number greater than one.

With a minor modification, this same formula can be used to estimate the present value of past damages. Specifically, it provides an estimate of the present value of damages t years in the past by putting a negative sign in front of the exponent in the denominator of the right-side of the formula.

The discount rate is an important determinant of present values. A larger discount rate results in a larger denominator for future values, which leads to a smaller present value. Analogously, a larger discount rate results in a smaller denominator for past values, which leads to a larger present value. The opposite is true for smaller discount rates. Table 4 illustrates the sensitivity of the present value of damages to different discount rates for different mixes of past and future damages. For each combination of years and discount rate, the present value is shown for a $100,000 annual loss for 20 years.

Table 4. Sensitivity of natural resource damages to different discount rates and time periods

Discount Rate (%)	Present Value (1994) of $100,000 Annual Loss Occurring From		
	1975–1994 ($\$10^6$)	1989–2008 ($\$10^6$)	1994–2013 ($\$10^6$)
2	2.4	1.8	1.7
6	3.7	1.6	1.2
10	5.7	1.5	0.9

Note: All values are in real terms.

Because natural resource damages are sensitive to the discount rate used to calculate total damages, it is important to select the appropriate rate. Unfortunately, there is considerable debate over the correct discount rate. DOI's NRDA regulations require the use of the discount rate specified in the Office of Management and Budget Circular A-94, which is 7%. However, most economists feel that 7% is too high because it reflects the expected rate of return on investments. Economists think that 3-4% is a more appropriate discount rate because it better reflects the public's trade-off of consumption over time (Lind 1982).

Table 5 shows the effect of the timing of restoration costs and compensable values on natural resource damages for three hypothetical restoration alternatives and the resulting compensable values.

Table 5. Hypothetical example of the effect of timing of restoration costs and compensable values on natural resource damages

	Restoration alternatives		
	A ($\$10^6$)	B ($\$10^6$)	C ($\$10^6$)
Restoration costs			
Year 1	0	60	15
Year 2	0	0	10
Year 3	0	0	5
Compensable values			
Year 1	20	12	16
Year 2	18	10	14
Year 3	16	8	12
Year 4	14	6	10
Year 5	12	4	8
Year 6	10	2	6
Year 7	8	0	4
Year 8	6	0	2
Year 9	4	0	0
Year 10	2	0	0
Damages (not discounted)	110	102	102
Present value of damages (based on 4% discount rate)	98.2	99.4	95.1

Restoration alternative A is a no-action alternative where natural resource services are allowed to return naturally to baseline, thereby incurring no restoration costs. This results in a gradual decline in compensable values over a 10-year period. Restoration alternatives B and C are more intensive, incurring restoration costs and reducing compensable value more quickly. For each alternative, the resulting damages equal the sum of the compensable values and restoration costs. The undiscounted damages for alternative A are $110 million, while the undiscounted damages for B and C are $102 million. However, if the future values are discounted to their present value, we find that alternative C minimizes total damages. Under alternative A, there are no up-front costs but compensable values are high for a longer period of time. In contrast, the up-front restoration costs of alternative B are too high relative to the reduction in compensable value that is achieved in the future.

5.7 SUMMARY OF DAMAGE DETERMINATION

Natural resource services are typically valued using a nonmarket valuation approach because most natural resource services are not traded in a market. The values of nonmarket natural resource services are based on the economic concept of consumer surplus. Consumer surplus is the maximum amount people are willing to pay for a natural resource service minus their total expenditures in receiving the services.

The value of natural resource services forgone as a result of a hazardous substance release is estimated by multiplying the consumer surplus per unit of natural resource services by the reduction in the number of units of natural resource services attributable to the release. This provides an estimate of the compensable values component of natural resource damages.

Total natural resource damages are the sum of restoration costs, compensable values, and assessment costs. This total is estimated in present-value terms by discounting and then summing annual estimates of restoration costs, compensable values, and assessment costs in the past and future.

6. INTEGRATING THE CERCLA AND NRDA PROCESSES

In this section, we summarize the recommended approaches derived from our work and discussions with the SRS staff during the project.

6.1 GOALS OF INTEGRATION

By integrating the CERCLA and NRDA processes, DOE hopes to achieve three goals, all of which should help reduce CERCLA and NRDA costs. The first goal is to incorporate NRDA data considerations into the CERCLA RI/FS to make data collection for both processes more efficient. The second goal is to incorporate natural resource damage considerations into the selection of remedial actions, so that the best remedial action can be selected. The third goal is for DOE to obtain “irreversible/irretrievable” liability exclusions in instances where the selected remedial actions are expected to increase natural resource damages.

6.2 GENERAL MODEL FOR PROCESS INTEGRATION

Both the CERCLA and NRDA processes have well-defined steps. (The requirements and procedures of NRDA have been summarized in EH-231, 1993, and Sharples et al. 1993.) Figure 17 is a flowchart illustrating the major steps in the two processes and indicating the linkages between them. RI/FS steps, at the left, are completed at the OU level. The components of a standard NRDA, at the right, are completed at the sitewide, or "area" level. To integrate the two processes, each must be timed appropriately and some intermediate steps taken to coordinate data collection efforts. These intermediate steps are indicated in the middle of the flowchart under the heading DOE Integration Process. Some of these integration steps are completed at the OU level and some are completed at the area level.[3]

It should be emphasized that Fig. 17 contains a great deal of information on the timing of the steps in an integrated process under ideal conditions. For example, early contact with the cotrustees is strongly recommended to afford the opportunity for trustee concerns to influence the design of data collection during RI. Failure to allow trustee participation in the design of data collection may mean that some aspects of RI will have to be revised by adding new efforts after work is already under way, or, even worse, that some data may have to be collected in a separate effort after RI is finished. The timing of other steps may, however, have much greater flexibility. For example, PAS can be performed after the completion of the baseline risk assessment or after the formulation of the qualitative damage assessment following completion of FS. It can also be delayed until after an OU restoration plan is developed. Thus, integrating the processes may follow a variety of paths depending upon circumstances unique to the site.

[3]By "area level" we mean a river basin, watershed, or some other large area in which the natural resources and their services are ecologically linked. Typically, an NRDA area will include the DOE site and off-site resources, such as an off-site river that receives water from on-site streams.

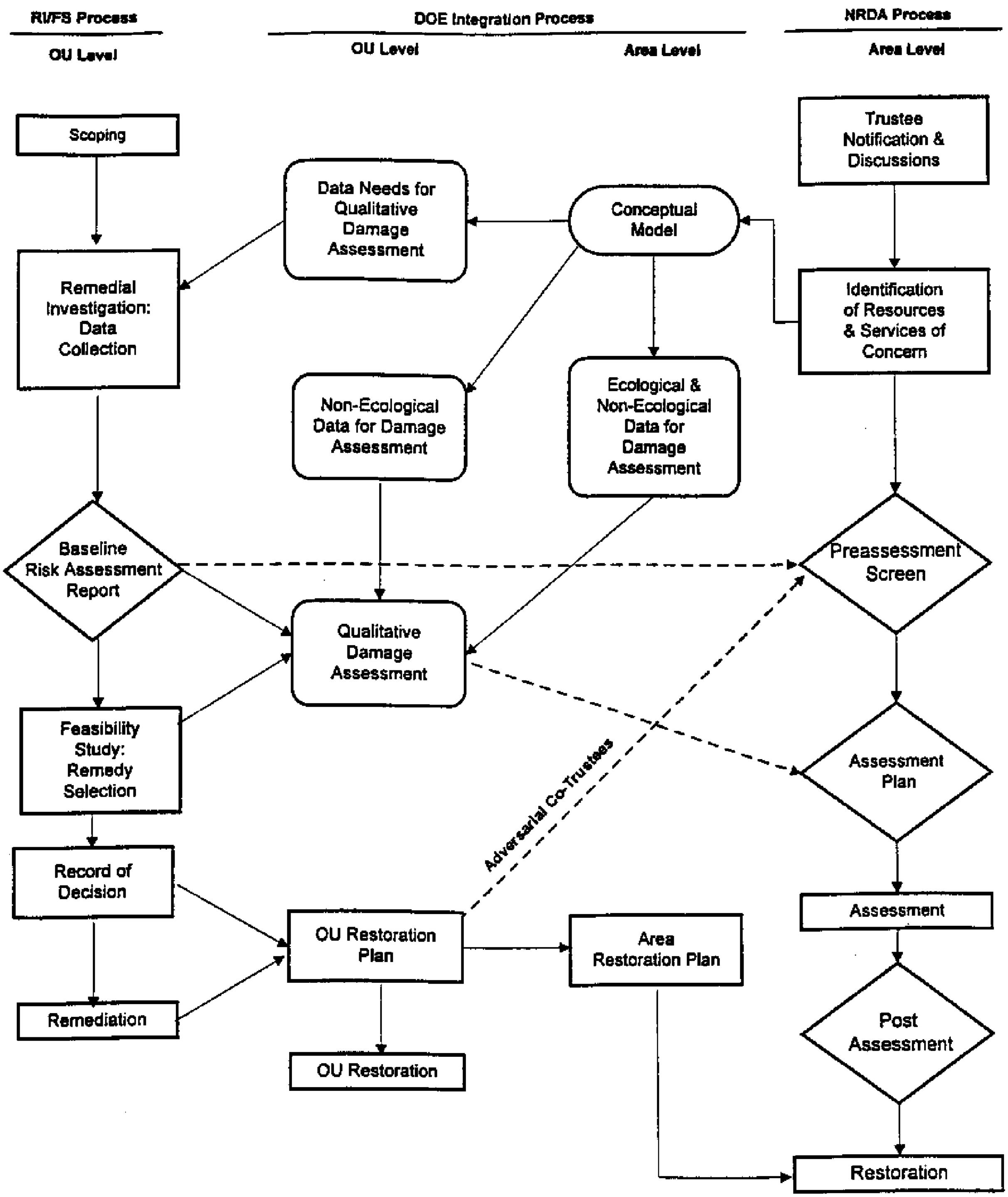

Fig. 17. Flowchart for integrating Comprehensive Environmental Response, Compensation, and Liability Act and Natural Resource Damage Assessment processes before the state of the remedial investigation (RI)

Ideally, NRDA data needs should be integrated into the RI data collection effort from the outset. Disconnects in timing, lack of funds, or other reasons may, however, produce difficulties, with the result that some NRDA data may have to be gathered outside of the CERCLA framework in a separate effort.

One of the key elements of the proposed approach is the influence of NRDA concerns on the evaluation and selection of remedial alternatives in the FS. Where no attempt is being made to integrate, remedy evaluation and selection are based solely on EPA criteria and do not include any consideration of natural resource damages. When integrating, the cost of each remedial action alternative, which is one of EPA's nine criteria, should be broadened to include an estimate of natural resource damages related to that alternative. We refer to this broader view of remedial action costs as their "life-cycle" cost, because it includes the natural resource damage impacts of the remedial actions in addition to their capital, operating, and maintenance costs. Since natural resource damages are partially determined by the "residual" injuries to natural resources following remediation, life-cycle cost is the appropriate measure of remedial action cost. Other things being equal, the public interest would be best served by selecting the remedial action that results in the lowest life-cycle cost, because this remedial action will minimize the combined cost of the remedial action and the resulting natural resource damages.

We recommend the following five-step approach to selecting the best remedial actions (see Fig. 18). The first step is to identify feasible remedial action alternatives. Next, the implementation costs for each alternative, including capital and operating costs, should be estimated. These first two steps are a standard part of an FS. The third step is to develop qualitative natural resource damage estimates for each alternative, assuming no restoration activities will follow remediation.[4] The fourth step is to estimate the life-cycle cost of each alternative by combining the implementation costs and the qualitative natural resource damage estimates. Finally, each alternative should be evaluated based on EPA's nine criteria, but with life-cycle costs replacing implementation costs.

As usual, the ROD follows FS and officially reports the remedial actions that will be undertaken. Once the remedial actions are officially selected, DOE can develop a restoration plan for OU with input from the cotrustees. This OU restoration plan should take into account the residual injury and associated service losses during and after remediation and the service reductions prior to the start of remediation. If the cotrustees agree with the OU restoration plan, then DOE can

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[4]We assume no restoration activities following remediation to simplify the task of developing qualitative natural resource damage estimates. From an efficiency point of view, restoration activities should not be undertaken unless they lower natural resource damages. Accordingly, assuming no restoration following remediation leads to worst-case natural resource damage estimates.

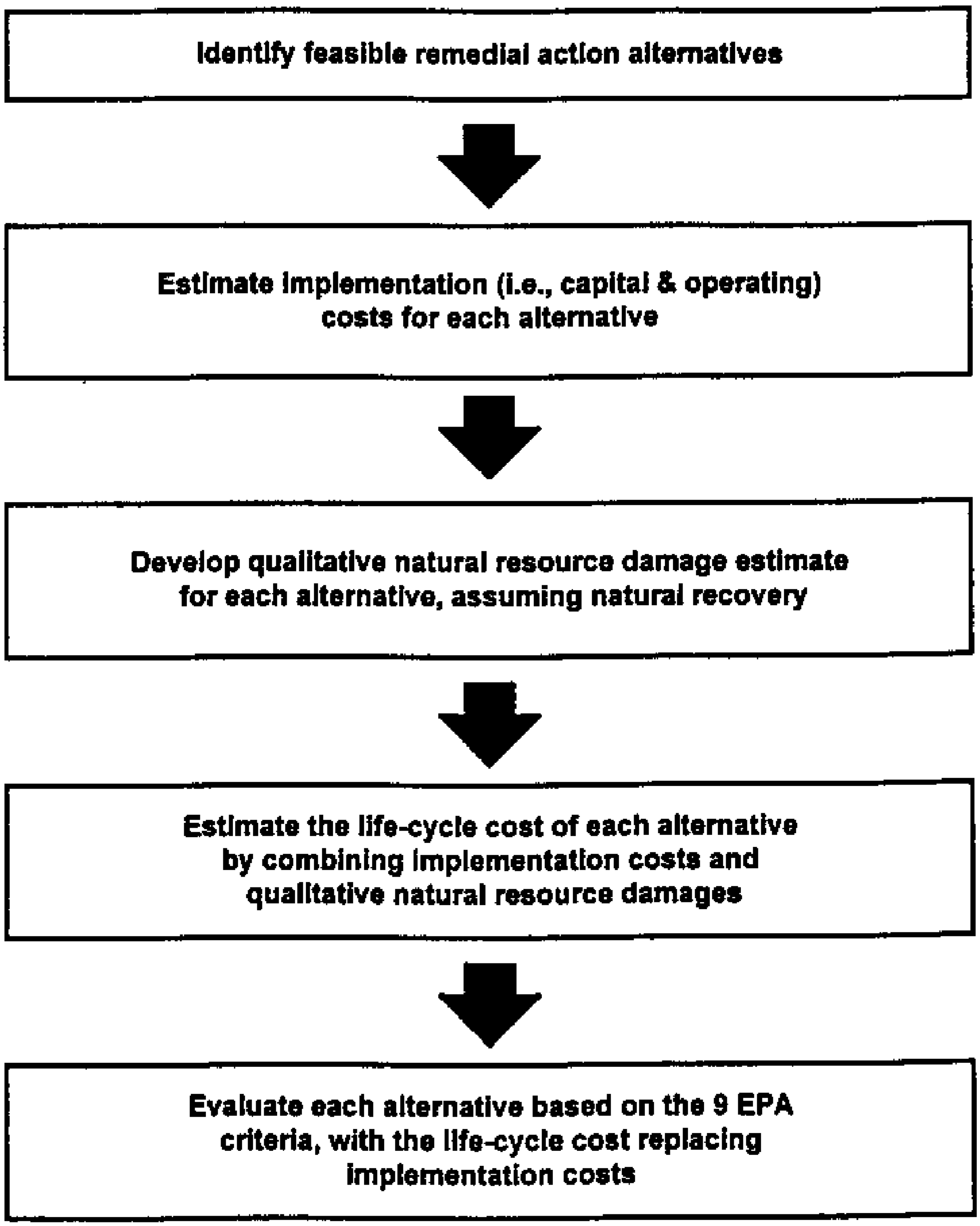

Fig. 18. Proposed approach for selecting the best remedial action.

implement it. If one or more of the cotrustees does not agree with the restoration plan, then a formal NRDA may be necessary. In such a situation, the baseline RA report will be helpful in conducting the PAS. Assuming that a formal NRDA is warranted, a qualitative NRDA (see below) may be helpful in developing the Assessment Plan.

Over time, restoration plans at various OUs will be assimilated into the area restoration plan. Normally, the area restoration plan is not fully implemented until remediation is complete or almost complete at all OUs in the area. Otherwise, the efficacy of restoration actions at the area level may be undermined by additional contamination from OUs that have not been remediated.

6.3 QUALITATIVE NATURAL RESOURCE DAMAGE ESTIMATES

Figure 17 and the foregoing text refer to the use of "qualitative natural resources damage assessments" to influence the outcome of remedy selection. The level of specificity in producing such a qualitative assessment depends largely on the amount of available data and the amount of effort that is devoted to acquiring additional data. In cases where data are very limited and little effort to acquire additional data is possible, the qualitative NRDA may only identify and describe the types of injuries, service reductions, and damages associated with each remediation alternative. However, with more available information, an ordinal ranking of the remediation alternatives with respect to natural resource damages may be possible. For example, an ordinal ranking may be possible when a reduction in services can be estimated, but values for these services are not available. Finally, when sufficient service quantification and valuation data are available and/or can be collected, it may be possible to estimate a range of natural resource damages for each remedial action alternative. The lower end of this range would reflect the best-case scenario, while the upper end of the range would reflect the worst-case scenario.

The remainder of this section will be used to describe the advantages and disadvantages of the descriptive, ordinal, and range approaches for estimating damages.

6.3.1 Descriptive Approach

Using the descriptive approach to estimate damages has several advantages. First, it requires minimal data and minimal modeling and analysis. The descriptive approach is also very helpful when the implementation costs of alternative remedial actions are similar but the natural resource injury and service impacts of these alternatives differ. For example, assume there are two remediation alternatives to eliminate contamination in a lake. The first remediation alternative is to drain the lake, remove the contaminated sediments, and refill the lake. The second remediation alternative is to treat the contaminated water in the lake. If the costs of these alternatives are similar, then a description of the natural resource injuries and service reductions associated with each alternative will be sufficient for identifying the alternative with the smallest life-cycle cost.

There are two disadvantages of the descriptive approach. First, the descriptive approach is not very helpful when all of the remediation alternatives affect the same resources and services. Second, the descriptive approach may not be useful when alternative remedial actions have substantially different time frames. As noted in the damage determination section, the timing of compensable value losses can have an important effect on natural resource damages. Since compensable values are not estimated in the descriptive approach, the timing of these losses cannot be quantitatively incorporated in life-cycle costs.

6.3.2 Ordinal Approach

The ordinal approach to estimating damages has several advantages, all of which are similar to those of the descriptive approach. First, the ordinal approach requires modest levels of data and modeling efforts. In addition, the ordinal approach is well-suited for cases where the implementation costs of alternative remedial actions are similar. However, the ordinal approach has two drawbacks. The first is that the approach may not be very helpful when the implementation costs of alternative remedial actions differ substantially. The second drawback is that it may be difficult to rank the natural resource damages associated with alternative remedial actions that have substantially different time frames.

6.3.3 Range Approach

There are several advantages to the range approach of estimating damages. It allows decisionmakers to quantitatively estimate the life-cycle costs for remediation alternatives. The range approach also incorporates both the magnitude and timing of the natural resource damages associated with each remedial action. Finally, the range approach is very helpful when remedial alternatives have substantially different time frames and/or implementation costs.

There are two disadvantages to the range approach. The first disadvantage is that the range approach has substantial data requirements. The second disadvantage is that the range approach requires extensive modeling and analysis, which is very time consuming.

6.4 DATA NEEDS FOR QUALITATIVE DAMAGE ASSESSMENTS

The data required for a qualitative damage assessment can be divided into two groups: OU-level data and area-level data. OU-level data are the data collected at an individual OU for the purpose of studying that site. Area-level data are on-site and off-site data collected for a particular watershed or river basin. The OU-level data needs for a qualitative damage assessment are

- type and timing of hazardous substance releases,
- pathways linking hazardous substance releases and natural resource injuries,
- type, extent, and timing of natural resource injuries,
- type, extent, and timing of service reductions, and
- value of affected services.

The area-level data needs for a qualitative assessment are

- pathways linking hazardous substance releases at the OU to area-level natural resource injuries,
- type and extent of area-level natural resource injuries linked to releases at the OU,
- type and extent of area-level service reductions associated with the natural resource injuries linked to releases at the OU, and
- value of affected area-level services.

6.5 POTENTIAL INTEGRATION CHALLENGES

DOE faces several obstacles in fully integrating CERCLA and NRDA processes. The most difficult challenge will be convincing stakeholders that integration is a good idea because it ultimately reduces taxpayers' costs. Integrating CERCLA and NRDA processes will undoubtedly increase DOE costs in the short run because NRDA activities that would normally occur after the completion of the RI/FS process will be implemented sooner (i.e., during the RI/FS process).

Similarly, NRDA restoration activities will probably be implemented sooner when the CERCLA and NRDA processes are integrated, which means that DOE will incur the costs of these activities sooner than if the damage assessment were conducted after the RI/FS process. However, integrating the two processes should result in substantial savings to DOE in the long run for several reasons. First, this integration will help DOE avoid costly litigation with the cotrustees. Second, selecting remedial actions with the lowest life-cycle cost leads to lower natural resource damages. Third, DOE may not be liable for natural resource damages resulting from irreversible/irretrievable commitments of the natural resources associated with some remedial actions. Finally, implementing restoration activities sooner will lower compensable value losses, which lowers natural resource damages.

The second challenge will be a short-term budget issue. It may prove difficult to obtain necessary funding for the supplemental data-collection efforts, modeling, and analysis needed to integrate the two processes. It should be remembered that the additional funding will go towards a pro-active attempt to reduce future costs resulting from formal NRDAs.

The third challenge is using the qualitative assessment properly. It is important to remember that qualitative natural resource damage estimates are based on predicted residual injuries and service reductions following proposed remedial actions at some proposed future time and will be subject to substantial measurement error. These estimates should be used as planning tools, not as definitive measures of natural resource damages.[5]

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[5]The compensable value losses in the past are the same for all remedial action alternatives, because these losses occur prior to the selection and implementation of remedial actions. Consequently, the qualitative natural resource damage estimates can focus exclusively on future compensable value impacts of the remediation alternatives. In this situation the qualitative damage estimates would not provide definitive measures of total natural resource damages even under the range approach.

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