CHAPTER 3
THE HRS SCORING PROCESS

This chapter provides an introduction to the process by which HRS packages are prepared, identifies the elements of a complete package, describes the package review process, and discusses effective scoring strategy. The approach and strategy for implementing the HRS discussed in this chapter are very broad; Chapters 4 through 10 and Appendix A present more specific guidance for scoring particular pathways, threats, and factors.

3.1 GENERAL APPROACH TO HRS SCORING

This section outlines an eight-step approach that breaks down the HRS scoring process into a series of manageable tasks. Although geared to the inexperienced HRS scorer, this approach can serve as a guide for experienced scorers as well. The approach presented here is only a suggested one; experienced scorers may develop their own approaches. In addition, because every site is different, an approach appropriate for one site may be inappropriate for another.

Throughout the scoring process, all information used in scoring must be recorded in the HRS documentation record. EPA has developed a computer software package (and companion user's manual) called PREscore, which automates HRS scoring and allows the scorer to enter limited narrative descriptions of scoring rationales and data sources. The PREscore printout can serve as a starting point for the final HRS documentation record. See ***Highlight 3-1*** for an introduction to PREscore.

HIGHLIGHT 3-1
THE PRESCORE SOFTWARE PROGRAM

The PREscore software package includes the PREscore and PREprint computer programs, as well as a users manual and tutorial (OSWER Dir. 9345.1-04). PREscore provides an efficient and convenient means of scoring sites using the HRS. PREscore performs HRS calculations from some raw data, retrieves values from hazardous substance reference tables, and calculates pathway and sites cores. PREprint generates HRS score sheets, an HRS documentation record, and an NPL characteristics data collection form. The user's manual provides instruction for installing and using PREscore and PREprint.

PREscore partially automates HRS scoring, allowing for entry and evaluation of site-related information such as sampling data, waste quantities, waste characteristics, physical parameters of the site, and population data. Scorers can enter descriptive narrative text and reference citations to document the selection of specific HRS factor values and scoring decisions.

PREscore users must be familiar with the HRS. The software does not provide detailed HRS instructions, although help screens with text from the HRS are available throughout the program. PREscore contains HRS related information on over 300 hazardous substances that may be encountered at Superfund sites. This information includes substance characteristics (such as toxicity and persistence) and concentration benchmarks.

For more information on PREscore, contact the appropriate Regional NPL Coordinator.

STEP 1: ASSEMBLE AND REVIEW ALL AVAILABLE SITE INFORMATION

Scorers often have limited first-hand knowledge of a site when they begin an HRS evaluation. Thus, the first step is to become familiar with the site by assembling and reviewing existing documents, a step sometimes referred to as a "file search." The PA and SI reports should contain most of the relevant site data collected to date. In addition, any preliminary HRS scoring results (e.g., PA-Score results) should be reviewed as a means of generating hypotheses about which pathways and factors are likely to be most significant in scoring the site.

When reviewing available information about a site, be sure to consider the following questions:

- What are the primary sources at the site? Are other (i.e., not part of the site) potentially important sources of hazardous substances nearby? (As in the HRS rule, the term "hazardous substance" is defined in this guidance document to include both CERCLA hazardous substances and CERCLA pollutants or contaminants; see Section 2.4 for additional related discussion.)

- What hazardous substances are associated with the site, and in what quantities are they present? Are they at least partially attributable to sources at the site?

- Have any observed releases or areas of observed contamination been documented?

- Are there any major targets (e.g., populations, municipal wells, fisheries, sensitive environments) located near the site (i.e., within the TDLs)? Are any targets located on or very near (e.g., within 1/2 mile) sources at the site?

- Are any targets exposed to actual contamination that is at least partially attributable to the site? If so, are there any data indicating the hazardous substance concentrations to which targets have been exposed?

The answers to these questions will provide a basic understanding of the nature of the threat posed by the site and will assist in determining whether available information contains any significant "gaps" that require additional investigation.

The scorer also should consider up front the site definition (i.e., which specific sources and/or areas of contamination comprise the site) and the site's eligibility for the NPL (see Sections 2.1 and 2.5). Both of these issues should have been resolved before HRS scoring and package preparation begins, but the scorer should confirm that the issues have been addressed.

STEP 2: IDENTIFY AND CHARACTERIZE SOURCES

Understanding the sources (and, for the soil exposure pathway, areas of observed contamination) at a site is one of the keys to HRS scoring. The HRS defines a source as any area where a hazardous substance has been deposited, stored, disposed, or placed, plus any soils that have been contaminated through migration (contaminated media other than soil usually are not considered sources). A site may include multiple sources and/or areas of observed contamination.

With this definition in mind, review source-related information and complete the source characterization portion of the HRS documentation record. Describe the dimensions and identify the hazardous substances associated with each source, and classify each source into a source type category (the assigned category can vary by pathway). Then, for each source, determine the containment characteristics and evaluate hazardous waste quantity for each pathway.

Evaluate source information to determine if:

- A source has been eliminated through a qualifying removal action and there is no observed release is associated with that source (see Section 2.3).

- A source has a containment factor value of zero for each migration pathway and an attractiveness/accessibility factor of zero for the soil exposure pathway.

If either of these conditions applies, do not use the source in scoring the site.

STEP 3: IDENTIFY AND CHARACTERIZE SIGNIFICANT PATHWAYS

While the potential hazards should be described qualitatively (at a minimum) for all HRS pathways, some pathways and threats may not be scored for a particular site. The identification of significant pathways depends to a large degree on professional judgment based on knowledge of the site and preliminary HRS scoring results. As a general rule, a pathway should be considered significant at this early stage of the scoring process if either of the following conditions is met: (1) there is an observed release (or observed contamination) for that pathway; or (2) several major target areas are within the TDL for that pathway. See Section 2.2 for general considerations about scoring all pathways and Section 3.4 for more quantitative guidance on the efficiency of scoring particular pathways.

The following are some of the more significant HRS considerations and information needs when characterizing pathways to be scored. See Chapters 7 through 10 for more detailed pathway-specific guidance.

Ground Water Pathway

- Evaluate all aquifers used as sources of potable water. The aquifer that yields the highest score is used to evaluate the pathway.

- Identify the geologic formations present (including known aquifer boundaries, discontinuities, and interconnections), especially underlying aquifers used for drinking water supply. Identify any karst aquifers within the TDL.

- Determine whether there has been an observed release of a hazardous substance from the source(s) to one or more aquifers.

- Identify ground water uses and well locations within the TDL.

Surface Water Pathway

- Identify all surface water bodies within the TDL.

- Determine whether multiple watersheds exist. If so, evaluate all watersheds. The watershed that yields the highest score is used to evaluate the pathway.

- Evaluate the hazardous substance migration path(s), including the overland segment(s) (including runoff routes, distance from source to surface water) and the in-water segment(s) (including probable point of hazardous substance entry, TDL(s)) for all surface waters to which hazardous substances have been or have the potential to be released, or have floodplains that include a source at the site.

- Determine whether there has been an observed release of a hazardous substance from the source(s) to surface water.

- Evaluate waste characteristics carefully, particularly for the human food chain and environmental threats because the maximum waste characteristics factor category value is 1,000 (rather than 100) in these threats due to consideration of bioaccumulation potential.

- Identify surface water uses (e.g., drinking water intakes, fisheries) within the TDL.

- Identify all sensitive environments within the TDL.

- Determine which of the three threats (drinking water, human food chain, and environmental) should be scored. Human food chain and environmental threats may score high if a substance with a bioaccumulation potential factor value of 500 or greater is present.

- Evaluate whether the ground water to surface water component should be scored. Note that no specific guidance on this component is provided in this manual.

Soil Exposure Pathway

- Identify and delineate areas where hazardous substances have been documented within 2 feet of the surface and do not lie beneath an essentially impenetrable cover (i.e, the areas of observed contamination). If no such areas have been documented, assign a zero to the pathway score.

- Identify property boundaries for areas of observed contamination.

- Determine the 200-foot distance from areas of observed contamination for the resident population threat.

- Identify land uses within areas of observed contamination.

- Identify all terrestrial sensitive environments at least partially within areas of observed contamination.

- Determine the 1/4-mile, 1/2-mile, and 1-mile travel distances for the nearby population threat. (Travel distances need not be straight line measurements.)

Air Pathway

- Determine whether there has been an observed release of a hazardous substance from the source(s) to air.

- Evaluate gas potential to release for sources with gaseous hazardous substances and particulate potential to release for sources with particulate hazardous substances. Evaluate both for sources with both types of hazardous substances.

- Identify land uses within the TDL.

- Identify all sensitive environments in the TDL.

STEP 4: EVALUATE TARGETS FOR SIGNIFICANT PATHWAYS

Targets consist of people, sensitive environments, fisheries, and resources that potentially can be affected by a site. The HRS targets factor category is the only category that has no maximum value. The relative contribution of a particular target to the overall site score is determined by its assigned point value and the level of contamination to which the target is subject. For each significant

pathway, identify all targets within the appropriate TDL and determine whether they are exposed to Level I, Level II, or potential contamination.

The following is a list of general guidelines for evaluating targets by pathway. For more detailed guidance, see the appropriate sections of Chapters 7 through 10. Refer to Appendix A for additional information on sensitive environments.

Ground Water Pathway

- Identify all wells drawing water from the aquifer(s) of concern.
- Determine whether ground water wells are part of a blended water supply system (including blending with surface water intakes), as this will affect the targets calculations.
- Identify and evaluate standby wells and emergency ground water supplies.
- Identify private drinking water wells and determine populations that rely on them for drinking water. Some private wells are not used as drinking water supplies.
- Focus on populations subject to actual contamination (Level I or Level II or within 1 mile of a source, as these generally will dominate the targets factor category value. Do not, however, ignore large populations beyond 1 mile.
- Collect sufficient data to be confident that the population subject to contamination within each distance category falls within the range of populations assigned the same factor value.

Surface Water Pathway

- Estimate average annual flow for all streams and rivers within the TDL. If the site is near an ocean or the Great Lakes, estimate the depth of these water bodies within the TDL.
- Focus on targets subject to actual contamination (Level I or Level II) or located on water bodies with an average annual flow of 100 cubic feet per second or less (i.e., high value for dilution weight multiplier), as these generally will dominate the targets factor category value.
- If actual contamination of targets cannot be established, identify the presence of significant targets (drinking water intakes, fisheries, sensitive environments) and calculate target factor category values after applying the appropriate dilution weight for the water bodies in which these targets are located.
- Determine whether drinking water intakes are part of a blended water supply system (including blending with ground water wells), as this will affect the targets calculations.
- Identify and evaluate standby intakes and emergency surface water supplies.
- Evaluate nearest intake and food chain individual values.
- Collect sufficient data to be confident that the population subject to contamination within each distance category falls within the range of populations assigned the same factor value.

Soil Exposure Pathway

- Focus on the resident population threat; the nearby population threat rarely will affect the pathway score significantly.

- Determine whether observed contamination exists that is within the property boundary and within 200 feet of any residences, day care centers, schools, or work areas.

- Determine whether observed contamination exists in terrestrial sensitive environments.

Air Pathway

- Identify all individuals regularly occupying areas an or near sources.

- Focus on populations and sensitive environments subject to actual contamination (Level I or Level II) or within 1/4 mile of a source, as these generally will dominate the targets factor category value.

- Collect sufficient data to be confident that the population subject to contamination within each distance category falls within the range of populations assigned the same factor value.

STEP 5: COLLECT ADDITIONAL INFORMATION, IF NECESSARY

At this stage of the HRS scoring process, the scorer should assess whether the available information is sufficient to document all the HRS factors relevant to the site's score. If not, collect the additional information needed. This may include verifying target populations. Additional sampling may be considered for a number of reasons, including:

- To score all HRS factors for all significant pathways;

- To replace low-quality chemical analysis data that support observed releases, and/or the calculation of targets exposed to actual contamination;

- To replace other low-quality data, if required;

- To attribute hazardous substances to sources at the site; and/or

- To establish representative background levels (in most cases, additional "release" samples would need to be collected at the same time background levels are established).

This step will not be necessary for all sites. In general, additional data collection at this point should focus on those factors critical to the site's HRS score.

STEP 6: CHECK VALIDITY OF FACTOR VALUES

The calculation of factor values should be reviewed to determine whether the 'best" data available have been used for scoring and whether the professional judgments made in scoring are appropriate. It is strongly recommended that inexperienced scorers consult more experienced scorers for this review. Areas that require a particularly thorough review include:

- Source characterization
- Hazardous waste quantity
- Aquifer boundaries, discontinuities, and interconnections
- Quality of sampling data

- Observed releases
- Extent of observed surficial contamination
- Documentation of targets exposed to Level I or Level II contamination
- Factor values for which data are near scoring range boundaries.

STEP 7: ASSEMBLE AND SUBMIT COMPLETE HRS PACKAGE

When assembling the HRS package, it may be helpful to prepare a working draft of the documentation record, indicating raw data values and the references used to support specific HRS factors. Use the working draft to enter information into PREscore (see ***Highlight 3-1***), which will convert the input data into factor, pathway, and site scores. More detailed information on the HRS scoring package itself is provided in Section 3.2. The completed HRS package is submitted to the appropriate EPA Regional office for review.

STEP 8: RESPOND TO REVIEWS

The EPA Regional QC review process will identify potential problems with the HRS package. If QC indicates that an HRS score is inaccurate or that the documentation is incomplete, the scorer must work with the Region to resolve any problems before the package is submitted to EPA Headquarters for QA review. Only sites scoring at or above the cutoff of 28.50 are submitted for QA review. See Section 3.3 for more information on the HRS package review process.

3.2 THE HRS SCORING PACKAGE

A complete HRS scoring package consists of the following materials (in order):

(1) A site narrative summary
(2) A signed QC checklist (completed by Regional reviewer)
(3) A QA signature page (completed by EPA Headquarters)
(4) HRS scoresheets (hard copy and disk; should be from PREscore)
(5) HRS documentation record, including bibliography of references
(6) Complete copies of referenced reports or documents, including legible maps (with scales) of sampling points and target locations
(7) NPL characteristics data collection form
(8) Other information as appropriate (e.g., RCRA documentation).

This section focuses on the materials most important to the HRS scorer, the documentation record and references. Refer to EPA's *Regional Quality Control (QC) Guidance for NPL Candidate Sites* (OSWER Publication 9345.1-08, December 1991) for information on other materials listed above.

THE DOCUMENTATION RECORD

The documentation record is the central element of the HRS package. It contains all of the information upon which a site score is based and a list of the references from which the information was obtained. The documentation record and references for sites proposed to the NPL are available for public review. If a site's listing is challenged in court, EPA's defense of the site score is restricted to the information contained in the documentation record. To refute legal challenges, information in the HRS documentation record must be objective, accurate, and complete. Every statement of fact in the record that is not a matter of general public knowledge should be supported by a reference number and a page number. Although the use of professional judgment is acceptable where appropriate, the documentation record should not contain assertions based strictly on opinion.

As a general rule, HRS documentation should be sufficient for an independent observer to replicate the observations, measurements, and calculations and arrive at the same quantitative or qualitative decision (factor value). More specific guidance on the HRS documentation record includes:

- All HRS factors that are scored must be documented in the documentation record.
- Adequate documentation of observed releases or observed contamination is extremely important. Be certain they are documented carefully and thoroughly.
- "Proof" is not required for documenting a factor value. The HRS has been designed with wide scoring ranges for many factors, reflecting the uncertainties in Sl data.
- An entry in the documentation record should include a reference to the supporting documents upon which the information is based (e.g., reports, well logs, geologic investigations). Always include the appropriate reference page number(s).
- Take particular care in documenting factor values upon which the final site score is critically dependent. Successful challenges to these factor values could prevent a site's placement on the NPL.
- Delete pages of the documentation record relating to HRS factors, pathways, and threats that have not been evaluated.
- Be as specific as possible given the available data. For example, do not indicate the HRS range into which site information falls (e.g., nearest well is 1/4 mile to 1/2 mile from Source A) when more precise information (e.g., 1,500 feet) is available.
- When information is close to a "break point" in an HRS scoring range, estimate it as precisely as possible.
- Show all intermediate calculations in documenting hazardous waste quantities, blended target populations, and food chain production. Do not merely list the final values for these (and similar) factors.
- Remember that incomplete entries in the documentation record could form the basis of challenge to the scoring during public comment; support all entries with sufficient references.

REFERENCES

A complete list of references, including the number of pages in each, should be included at the front of the documentation record. Number references sequentially in the order in which they are cited in the documentation record, with the following exceptions:

- List the HRS as reference 1; and
- List the version of the Superfund Chemical Data Matrix (SCDM) used as reference 2. ***Highlight 3-2*** provides more details on SCDM.

Include a complete copy of most references cited in the documentation record (except references 1 and 2, listed above) in the HRS scoring package. For unusually lengthy references, provide only the appropriate excerpts and the title page. For any document that is not publicly available (e.g., those phone logs, PA/Sl reports, consultant reports), include a complete copy, regardless of length. Maps (e.g., those indicating sampling points, target locations) must be legible and include distance scales.

HIGHLIGHT 3-2
THE SUPERFUND CHEMICAL DATA MATRIX

SCDM contains data for more than 300 chemicals frequently found at Superfund sites. For each substance, SCDM provides selected HRS factor values (primarily for contaminant characteristics) and HRS benchmarks for each of the four pathways. HRS factor values listed include: toxicity, groundwater mobility, surface water persistence, human food chain and environmental bioaccumulation, ecosystem toxicity, air gas migration potential, and air mobility. Available benchmarks for all four pathways include toxicity-based benchmarks (e.g., cancer risk and reference dose screening concentrations) and regulation-based benchmarks (e.g., Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) promulgated under the Safe Drinking Water Act). SCDM is essential for HRS scoring because benchmarks and HRS factor values are found more easily in SCDM than by consulting primary references.

SCDM is published by EPA and is updated periodically.To obtain a copy of SCDM, contact the Hazardous Site Evaluation Division at EPA Headquarters.

When referencing target measurements, describe where the measurement began (e.g., the identified PPE), where the measurement ended (e.g., a specific sampling location), and how the measurement was made (e.g., measured during the SI, or estimated from a map). This description enables reviewers to repeat each step of the measurement and verify the supporting information in the references.

Whenever possible, ensure that references cited are primary sources; that is, the original material from which the information was obtained. Examples of primary sources are:

- Geologic publications
- Records of field observations/measurements
- Analytical data reports
- Waste manifests
- Phone logs
- Field notebooks
- Contractor's reports.

Examples of references that can be used but are not considered primary references are:

- Summaries of analytical results with the appropriate QA/QC information
- PA or SI reports.

Examine very carefully the use of PA and SI reports as references. In addition to actual field observations or measurements and sampling results, these reports may contain summaries of information gathered from other documents. Ensure that the documents referenced within the PA and SI reports are reviewed and used as the primary references in the HRS documentation record.

OTHER ITEMS IN THE HRS SCORING PACKAGE

Other items in the HRS package include:

- The HRS scoresheets, which list HRS factor values, pathway and threat scores, and the total site score.

- The site narrative summary, which is a brief description of the site including the site's name, location, approximate size, general nature of contamination problem, and a description of current status of any response actions or enforcement actions.

- The QC checklist which is filled out and signed by the Regional site assessment personnel responsible for performing QC review of HRS packages before submitting them to EPA Headquarters for formal QA.

- The NPL characteristics data collection form, used to update an EPA data base of NPL sites.

- The QA signature page, which is signed by the EPA Headquarters Regional Coordinator and Site Assessment Branch Chief, indicating that all QA issues have been resolved and that the site is ready for proposal to the NPL.

In some cases, other information is included in the HRS package. For example, when multiple sources that are some distance apart or otherwise may appear unrelated are treated as a single site, a statement of the rationale for doing so – a document sometimes referred to as an aggregation memorandum – may be part of the HRS package. As another example, the package may include a statement regarding the use of RCRA permits to document hazardous waste quantity.

3.3 THE PACKAGE REVIEW PROCESS

All HRS scoring packages developed by states and EPA contractors are subject to QC review by EPA Regional site assessment staff. EPA Headquarters will not review any package that has not completed Regional QC and is not accompanied by a signed QC checklist. The purpose of the Regional QC is to:

- Confirm the eligibility of a site for the NPL;

- Verify that the package is complete, information is accurate and readable, and every statement of fact is supported by documentation in the package;

- Check the arithmetic;

- Ensure that scores for individual HRS factors are appropriate, given the information contained in the package;

- Review key assumptions and professional judgments made in scoring the site and ensure that they are adequately explained and documented;

- Resolve and correct any errors or discrepancies; and

- Review the site narrative summary and NPL characteristics data collection form to ensure that they are adequate.

For more information on the QC process, refer to EPA's *Regional Quality Control (QC) Guidance for NPL Candidate Sites* (OSWER Publication 9345.1-08, December 1991).

After Regional QC is complete, packages undergo an in-depth QA review at EPA Headquarters. Analysis of HRS scoring packages submitted to Headquarters in the past shows a high incidence of incorrect referencing and illegible photocopies, especially of maps. Avoiding these common errors will streamline the review process considerably.

After any scoring errors or issues are resolved, EPA may propose adding sites scoring greater than 28.50 to the NPL through a proposed rulemaking in the *Federal Register*. Comments received during the ensuing public comment period are reviewed and addressed, and site scores modified as necessary. In some cases, site scores may drop below 28.50. A final rule is then published in the *Federal Register* identifying the sites added to the NPL (i.e., sites with scores remaining above 28.50 and remaining eligible under EPA's policy).

3.4 HRS SCORING STRATEGY

This section discusses a strategy for efficient HRS scoring. Guidelines are presented for determining the extent of scoring effort and the number of pathways to score. In addition, this section discusses the implications of the HRS equations for site scoring and provides several scoring principles that will help in preparing HRS packages.

The HRS evaluates hazards to human health and the environment on the basis of a large number of individual factors. For most sites, it is neither feasible nor productive to gather data for and score every factor in every pathway, because:

- One of the primary objectives of HRS scoring is to determine whether or not the site score is greater than 28.50 (i.e., cutoff score for NPL listing).
- Many sites pose threats primarily via one or two pathways.
- The mathematics of the HRS is such that higher-scoring pathways exert a proportionately greater influence on the site score than do lower-scoring pathways.

Without a clearly defined scoring strategy, considerable resources may be expended gathering data and scoring factors and pathways that will have little impact on the site score.

SCORING EFFORT

Scoring a site with the HRS involves various types of decisions. Quantitative decisions may include determining the correct scoring ranges for waste characteristics and targets. Qualitative decisions may include deciding which pathways, threats, aquifers, and watersheds to evaluate, and whether existing sampling results are sufficient to document an observed release or observed contamination. One of the most important decisions is determining when the data collection and scoring effort is complete.

The level of effort devoted to scoring a site is governed by two competing requirements: (1) to accurately determine the relative threat posed by the site, and (2) to efficiently use EPA's limited data collection and analysis resources. The HRS includes numerous factors that must be evaluated for each pathway scored, and comprehensive data are rarely readily available for every factor. Moreover, some factor evaluations are more resource-intensive than others. At most sites, it would be possible to refine factor values by gathering or analyzing additional data (e.g., take one more sample, count one more house), but such efforts may consume resources better devoted to other sites. It is important to have a strategy for accurately and efficiently scoring a site. The following general principles should help determine the extent of scoring effort:

- The HRS score should reliably reflect the site's eligibility for the NPL. If the site score is greater than or equal to 28.50, the scorer should be confident that the score will remain at or above 28.50 after QA/QC review and public comment. If the site score is less than 28.50, the scorer should be confident that additional scoring efforts would not raise the score to 28.50 or greater.
- To the extent practicable, the HRS score should reflect the relative threat posed by the site.

In developing a scoring strategy, the scorer must realize that the HRS is a screening tool, not a detailed risk assessment. Given the considerable uncertainties regarding specific characteristics of a site and its surrounding environment at the time of scoring, the HRS score should not be viewed as a measure of absolute risk that must be determined to the last decimal point. Moreover, qualitative information regarding specific site characteristics may be as important as the numerical HRS score in determining some aspects of relative threat. For example, the immediate threat a site poses as a

result of a few drinking water wells contaminated above health-based benchmarks would be greater than the immediate threat posed by a site at which nearby municipal wells were threatened with contamination (but not currently contaminated), even if the two sites received similar HRS scores.

IMPLICATIONS OF HRS EQUATIONS FOR SITE SCORING

Understanding the mathematical dynamics of the HRS requires familiarity with (1) the way in which the site score is determined from pathway scores and (2) the way in which pathway scores are determined from factor category values.

Dynamics of the HRS Site Score

The HRS site score (S) is calculated by a root-mean-square formula:

$$S = \sqrt{\frac{S_{gw}^2 + S_{sw}^2 + S_s^2 + S_a^2}{4}}$$

where: S_{gw} = ground water migration pathway score
S_{sw} = surface water migration pathway score
S_s = soil exposure pathway score
S_a = air migration pathway score.

Each pathway score has a minimum value of 0 and a maximum value of 100. The mathematics of the root-mean-square equation is such that higher-scoring pathways exert a proportionately greater influence on the site score than lower-scoring pathways. For example,

$$S = \sqrt{\frac{100^2+30^2+30^2+30^2}{4}} = 56.35$$

$$S = \sqrt{\frac{100^2+0^2+0^2+0^2}{4}} = 50.00$$

$$S = \sqrt{\frac{0^2+30^2+30^2+30^2}{4}} = 25.98$$

In the root-mean-square equation, the sum of the squared pathway scores is the key to reaching the cutoff score:

$$S = \sqrt{\frac{3,249}{4}} = 28.50$$

The value of 3,249 can be reached in a variety of ways, as shown by the examples in ***Highlight 3-3.***

HIGHLIGHT 3-3
COMBINATIONS OF PATHWAY SCORES THAT YIELD SITE SCORE OF 28.50

Individual Pathway Scores			Sum of Squared Pathway Scores	Site Score
57.00	0.00	0.00	3,249	28.50
40.31	40.31	0.00	3,250	28.50
32.91	32.91	32.91	3,249	28.50
28.50	28.50	28.50	3,249	28.50

The root-mean-square equation and ***Highlight 3-3*** illustrate that it is easier to raise a site score by adding points to a high-scoring pathway than by adding the same number of points to a second, lower-scoring pathway. Given an existing single-pathway score (A) less than 57, the additional score required for the same pathway to reach a site score of 28.50 is:

$$57 - A$$

whereas the score required for a second pathway is given by:

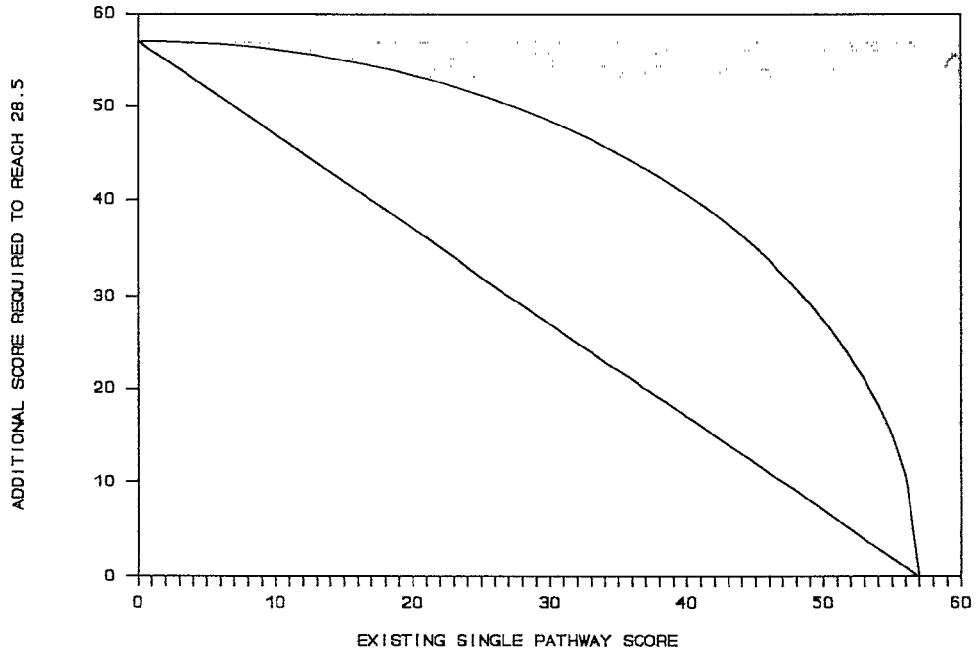
$$\sqrt{3{,}249 - A^2}$$

For example, suppose a preliminary scoring effort resulted in a single-pathway score of 50. Within that same pathway, only (57-50)=7 additional points would be required for a site score of 28.50, while in a different pathway, (3,249-2,500)=27.37 points would be required. ***Highlight 3-4*** presents the general relationship between additional points required within the same pathway versus a second pathway.

Several general conclusions can be reached from the dynamics of the algorithm used to derive the HRS site score:

- Knowing the two highest pathway scores usually is sufficient to determine whether the site score is likely to be above 28.50.
- The site score is unlikely to be above 28.50 unless one pathway score is greater than 50, two pathway scores are greater than 35, or three pathway scores are greater than 30.
- Pathways that receive a score lower than 10 points are unlikely to have a significant effect on the site score in the range of the cutoff score or above (e.g., a single-pathway score of 50 would result in a site score of 25.00; pathway scores of 50 and 10 would result in a site score of 25.50).

HIGHLIGHT 3-4
ADDITIONAL SCORE REQUIRED TO YIELD SITE SCORE OF 28.50



Dynamics of the HRS Pathway Scores

Each HRS pathway score (A) is the product of the three factor category values (likelihood of release or likelihood of exposure, waste characteristics, and targets) divided by a scaling factor:

$$A = \frac{LR \times WC \times T}{82{,}500}$$

where: LR = likelihood of release
WC = waste characteristic
T = targets factor.

The scaling factor of 82,500 results in a pathway score of 100 when the values for likelihood of release (or likelihood of exposure) and waste characteristics are at their "typical" maxima and the targets factor category value is 150 (i.e., (550 x 100 x 150)/82,500 = 100). However, several characteristics of the HRS scoring algorithms make it difficult to determine a *priori* for a specific site which factor category or individual factor has the greatest influence on pathway score:

- The multiplicative nature of the factor categories, which means, for example, that doubling any one factor category value will double the pathway score, is subject to certain maximum values (i.e., "caps").

- The hazardous substance used to determine toxicity and other waste characteristics factor values may vary among pathways and threats.

- Caps on the waste characteristics factor category value vary among pathways and threats.
- The maximum pathway score based solely on environmental threat is 60.
- The targets factor category has no cap.
- The point value assigned to specific targets depends on whether they are subject to actual contamination.

If the values for likelihood of release and waste characteristics are known (or have been approximated) for a pathway, the targets factor category value required to obtain a particular pathway score (A) is:

$$T = \frac{82{,}500 \times A}{LR \times WC}$$

For example, if likelihood of release is 550, waste characteristics is 32, and the pathway score required for a site score of 28.50 is 47.5, the minimum targets factor category value necessary for this score is (82,500 x 47.5)/(550 x 32) = 222.66. Assuming maximum values for likelihood of release and waste characteristics, the minimum targets factor values required for a pathway score of 57 (and hence a single-pathway site score of 28.50) are presented in ***Highlight 3-5***. Note that the targets factor category value includes Level I, Level II, and potential contamination values; values for nearest well, intake, or residence; and values for wellhead protection areas, workers, resources, sensitive environments, and other targets factors. The relative weight given each of these targets factors determines the overall contribution of a single target to the pathway and site score. For example, individuals and sensitive environments evaluated under Level I or Level II contamination are weighted, respectively, a minimum of 100 and 10 times more heavily than those evaluated under potential contamination.

A high pathway score generally requires relatively high values for all three factor categories, and with a few exceptions (e.g., when the targets category value, which is not capped, is very high) a low value for any single factor category will limit the pathway score. This results partly from the multiplicative relationship between the three factor category values in the pathway score equation, and partly from how the values for each factor category are assigned in the HRS. For example, minimal waste quantity and a moderate or low likelihood of release are likely to result in a low pathway score unless a very high targets value is obtained. A high targets value could be difficult to obtain in this scenario because all targets would be evaluated under potential contamination.

PATHWAY CONSIDERATIONS

Certain combinations of site characteristics usually result in a high pathway score. The following generalizations may help identify potentially high-scoring pathways:

- Pathways with actual contamination of targets are likely to score higher than pathways in which only potential contamination is established. Therefore, consider scoring all pathways with actual contamination of targets.
- The decrease in target values due to distance-weighting of targets subject to potential contamination is less in the ground water pathway than in the air and soil pathways (see ***Highlight 3-6*****).**
- The surface water pathway is likely to receive a relatively high score if an observed release to a fishery or sensitive environment is established.

HIGHLIGHT 3-5
MINIMUM TARGETS FACTOR VALUE REQUIRED TO YIELD PATHWAY SCORE OF 57

Pathway or Threat	Maximum Likelihood of Release Factor	Maximum Waste Characteristics Factor Category	Minimum Targets Factor Category Value for Pathway Score of
Ground Water	550	100	85.5
Surface Water			
Drinking Water	550	100	85.5
Human Food Chain	550	1,000	8.55
Environmental[b]	550	1,000	8.55
Soil Exposure			
Resident	550	100	85.5
Nearby Population[c]	500	100	94.05
Air	550	100	85.5

[a] Assumes maximum value for likelihood of release and waste characteristics; required targets factor value increases as values for likelihood of release and/or waste characteristics decrease
[b]Maximum Score for the environment threat is 60.
[C]A targets factor category value as high as 94.05 is unlikely for this threat.

- In the surface water pathway, the maximum value for waste characteristics is 1,000 in the human food chain and environmental threats. A waste characteristics value greater than 100 means the pathway can score > 57 with lower values for the likelihood of release and targets factor categories (see ***Highlight 3-5***).

- If the likelihood of release and waste characteristics factor values are maximum, a pathway or threat score of 57 or greater may result when actual contamination is established for between 4 and 41 persons (see ***Highlight 3-7***).

Several other generalizations for pathway scoring are presented below. For specific pathway and factor scoring strategies, see the appropriate chapters of this document.

Ground Water Pathway

The ground water pathway may receive a score of 57 or greater based on actual or potential contamination if target populations are sufficiently large.

- Score the ground water pathway if any targets are evaluated under actual contamination (Level I or II concentrations).

- Score the pathway if there is a large population within the TDL, even if all targets are evaluated under potential contamination.

- The nearest well factor may have a significant effect on the pathway score.

- A large distance-weighted population is most likely when a large number of private wells are within 1/2 mile of the site, municipal wells are within the TDL, and/or a karst aquifer is within the TDL.

HIGHLIGHT 3-6
DISTANCE AND DILUTION WEIGHTS UNDER POTENTIAL CONTAMINATION

Distance Category[a]	Relative Distance Weight Assigned to Population Targets Evaluated Under Potential Contamination		
	Ground Water Pathway [b]	Air Pathway	Soil Exposure Pathway [c]
Onsite	1.00	1.000	1.000
> 0.00 - 0.25	1.00	0.250	0.025
> 0.25 - 0.50	0.62	0.054	0.013
> 0.50 - 1.00	0.32	0.016	0.006
> 1.00 - 2.00	0.18	0.005	0
> 2.00 - 3.00	0.13	0.002	0
> 3.00 - 4.00	0.08	0.001	0

[a] Distance from source (miles).
[b] For karst aquifers, relative weight is 0.50 beyond 0.5 mile.
[C] Nearby population threat only.

HIGHLIGHT 3-7
POPULATION REQUIRED TO YIELD PATHWAY SCORE OF 57

Number of Persons Evaluated Under Actual Contamination		Pathway or Threat Score[a,b]
Level I	Level II	
4	0	60.00
3	6	57.33
2	16	57.33
1	26	57.33
0	41	57.33

[a] Pathway or threat score based solely on population evaluated under actual contamination (e.g., no resources, no sensitive environments).
[b] Ground water pathway, surface water pathway (drinking water threat), soil exposure pathway (resident population threat), and air pathway.

Surface Water Pathway

The surface water pathway score is the sum of the three separate scores for the drinking water, human food chain, and environmental threats. Any threat may score 57 or greater if actual contamination of targets is established; if actual contamination is established for either the human food chain or environmental threat, the surface water pathway is very likely to score 57 or greater.

- Score the surface water pathway if any targets are evaluated under actual contamination (Level I or II concentrations).

- Score the surface water pathway if there is an observed release to surface water and a fishery is present within the TDL, even If the fishery is not subject to actual contamination.

- If an observed release to surface water is not established, an individual threat is unlikely to score greater than 10 points unless many targets (or a large fishery) are present within a surface water body with a dilution weight of 0.01 or greater (for a list of such surface water body types, see HRS Table 4-13); however, the sum of the three threats may exceed 10.

- Within the surface water pathway, threat scores are additive (i.e., they are not combined using a root-mean-square equation), and therefore an individual threat score lower than 10 may contribute significantly to the pathway score.

- At many sites, several types of surface water bodies are located within the TDL.; therefore, targets within all surface water body types must be considered in developing a scoring strategy.

Drinking Water Threat

- A large dilution-weighted population is most likely when a municipal intake is located on a stream or river with low or moderate flow characteristics. The low dilution weight for large surface water bodies often will result in a low threat score, even when population served is large (for examples, see ***Highlight 3-8***).

- When evaluated based on potential contamination, the nearest intake factor generally will not have a significant effect on the drinking water threat score unless the intake is located within a minimal stream.

Human Food Chain Threat

- The human food chain threat score is likely to be 57 or greater if actual contamination of a fishery is established. If actual contamination is established and the waste characteristics value is 180 or greater, the human food chain threat score will almost always be 57 or greater.

- Even if actual contamination of a fishery is not established, the human food chain threat score is likely to be significant if there is an observed release to the watershed and the waste characteristics value is 100 or greater.

- If no observed release is established, the human food chain threat score is unlikely to be significant unless there is a fishery within a minimal or small to moderate stream and the waste characteristics value is greater than 320.

Environmental Threat

- The environmental threat score is likely to be 57 or greater if Level I concentrations are established for a sensitive environment with a point value of 25 or greater. If actual contamination is established for at least one sensitive environment and the waste characteristics value is 320 or greater, the environmental threat score will almost always be 57 or greater.

HIGHLIGHT 3-8
DRINKING WATER THREAT SCORES UNDER POTENTIAL CONTAMINATION

Type of Surface Water Body[b]	Drinking Water Threat Score for Intake with Given Population Served[a]				
	2,500	7,500	25,000	75,000	250,000
Rivers and Streams					
Minimal stream	98.79	100.00	100.00	100.00	100.00
Small to moderate stream	9.70	31.52	98.79	100.00	100.00
Moderate to large stream	1.21	3.03	9.70	31.52	98.79
Large stream to river	0.12	0.30	1.21	3.03	9.70
Large river	0.01	0.03	0.12	0.30	1.21
Very large river	0.0	0.0	0.01	0.03	0.12
3-mile mixing zone in quiet flowing river	49.70	100.00	100.00	100.00	100.00
Other Surface Water Bodies[c]					
Shallow ocean/Great Lake	0.01	0.03	0.12	0.30	1.21
Moderate depth/Great Lake	0.0	0.0	0.01	0.03	0.12
Deep zone/Great Lake	0.0	0.0	0.0	0.02	0.06

[a] Assumes likelihood of release value of 500, waste characteristics value of 100, and no other drinking water intakes within the TDL.

[b] For definitions, see HRS Table 4-13.

[c] Assumes no drinking water intakes in salt or brackish water; for other lakes, see HRS section 4.1.2.3.1.

- If actual contamination of a sensitive environment cannot be established, the environmental threat score is unlikely to be significant unless there are several sensitive environments within a minimal or small to moderate stream and the waste characteristics value is greater than 100.

- The maximum score for the environmental threat is 60.

Soil Exposure Pathway

The soil exposure pathway score is derived by combining separate scores for the resident population and nearby population threats. The soil exposure pathway is only evaluated when areas of observed (surficial) contamination are documented. The area of observed contamination is an important determinant of waste characteristics in the resident population threat and of likelihood of exposure and waste characteristics in the nearby population threat.

- Score the soil exposure pathway if any targets are within 200 feet of an area of observed contamination.

- The soil exposure pathway usually will not score 57 or greater unless residents, students (including day care), workers, or sensitive environments are on or within 200 feet of an area of observed contamination on the property.

- The nearby population threat is unlikely to contribute significantly to the soil exposure pathway score unless there is a very large population near the site and areas of observed contamination at the site are readily accessible.

- Within the soil exposure pathway, threat scores are additive (i.e., they are not combined using a root-mean square equation), and therefore an individual threat score lower than 10 may contribute significantly to the pathway score.

- The maximum soil exposure pathway score that can be achieved when the only targets are terrestrial sensitive environments is 60.

Resident Population Threat

- Evaluating a relatively small number of resident threat targets may result in a significant pathway score. For example, if the waste characteristics value is 32, documenting one resident and one 50-point sensitive environment both subject to Level II concentrations plus one worker would result in a pathway score of 21.55 (based solely on resident population threat).

Nearby Population Threat

- The nearby population threat score is likely to be significant by itself only if there is a large population very near the site and likelihood of exposure and waste characteristics are moderate to high.

Air Pathway

The air pathway may score 57 or greater based on actual or potential contamination. However, if all targets are evaluated under potential contamination, the pathway score is likely to be lower than 10 unless at least some targets are on or very near sources.

- Score the air pathway if any targets are evaluated under actual contamination (Level I or II concentrations).

- Score the pathway if there are any targets on or within 1/4 mile of sources at the site, even if all targets are evaluated under potential contamination.

- The relative value assigned to targets evaluated under potential contamination declines steeply with distance (see ***Highlight 3-6***). Therefore, the targets factor category value generally will be determined primarily by targets on or within 1/4 mile of a source.

- The maximum air pathway score that can be achieved when the only targets are sensitive environments is 60.