A Life-Cycle Model Approach to Multimedia Waste Reduction Measuring Performance for Environmental Cleanup Projects

Bernard E. Phifer, Jr.
Pollution Prevention Manager
Environmental Restoration Waste Management Program
Martin Marietta Energy Systems, Inc.*
Oak Ridge, Tennessee 37831

Sheri M. George
Project Manager
Roy F. Weston, Inc.
704 S. Illinois Avenue, Suite C-102
Oak Ridge, Tennessee 37830

Will be corrected per Stephanie Boone.

* Managing for the U.S. Department of Energy the Oak Ridge National Laboratory, Oak Ridge K-25 Site, Oak Ridge Y-12 Plant, and the Paducah Gaseous Diffusion Plant and Portsmouth Gaseous Diffusion Plant under contract ~~DE-AC05-76OR00001.~~

A Life-Cycle Model Approach to Multimedia Waste Reduction: Measuring Performance for Environmental Cleanup Projects

Bernard E. Phifer, Jr.[*]
Martin Marietta Energy Systems, Inc.[†]

Sheri M. George[‡]
Roy F. Weston, Inc.

Abstract

The Martin Marietta Energy Systems, Inc. (Energy Systems), Environmental Restoration (ER) Program adopted a Pollution Prevention Program in March 1991. The program's mission is to minimize waste and prevent pollution in remedial investigations (RIs), feasibility studies, decontamination and decommissioning, and surveillance and maintenance site program activities. Mission success will result in volume and/or toxicity reduction of generated waste.

The ER Program waste generation rates are projected to steadily increase through the year 2005 for all waste categories. Standard production units utilized to measure waste minimization apply to production/manufacturing facilities. Since ER inherited contaminated waste from previous production processes, no historical production data can be applied. Therefore, a more accurate measure for pollution prevention was identified as a need for the ER Program. The Energy Systems ER Program adopted a life-cycle model approach and implemented the concept of numerically scoring their waste generators to measure the effectiveness of pollution prevention/waste minimization programs and elected to develop a numerical scoring system (NSS) to accomplish these measurements.

The prototype NSS, a computerized, user-friendly information management database system, was designed to be utilized in each phase of the ER Program. The NSS was designed to measure a generator's success in incorporating pollution prevention in their work plans and reducing investigation-derived waste (IDW) during RIs.

Energy Systems is producing a fully developed NSS and actually scoring the generators of IDW at six ER Program sites. Once RI waste generators are scored utilizing the NSS, the numerical scores are distributed into six performance categories: training, self-assessment, field implementation, documentation, technology transfer, and planning.

---

[*]Pollution Prevention Manager, Environmental Restoration Waste Management Program, Oak Ridge, Tennessee 37831.
[†]Managing for the U.S. Department of Energy the Oak Ridge National Laboratory, Oak Ridge K-25 Site, Oak Ridge Y-12 Plant, and the Paducah Gaseous Diffusion Plant and Portsmouth Gaseous Diffusion Plant under contract DE-AC05-76OR00001.
[‡]Project Manager, 704 S. Illinois Ave., Suite C-102, Oak Ridge, Tennessee 37380.

As waste generators improve their numerical scoring, the expectation is that there should be a correlation in waste-volume reduction. This paper summarizes how this correlation of performance measurement and waste-volume reduction could be measured using a life-cycle methodology approach.

INTRODUCTION

The Energy Systems ER Program, as an integrating contractor, manages six environmental cleanup sites for the Department of Energy (DOE): the Oak Ridge K-25 Site (K-25 Site); the Oak Ridge National Laboratory (ORNL); the Oak Ridge Y-12 Plant (Y-12 Plant); the Clinch River/Offsite facility on the Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee; the Paducah Gaseous Diffusion Plant (Paducah) in Paducah, Kentucky; and the Portsmouth Uranium Enrichment Complex (Portsmouth) in Piketon, Ohio.

The central purpose of the DOE and Energy Systems pollution-prevention efforts is to reduce waste generated by the DOE facilities managed and maintained by Energy Systems. This should be accomplished through acceptable programmatic and regulatory standards within the constraints of available public funding. The creation of drilling cuttings, decontamination fluids, residual samples, and other investigation-derived waste (IDW) is the result of the investigations of previous contamination. A key objective of the Environmental Restoration (ER) Pollution Prevention Program is to establish performance measures to be implemented by the generator by means of a numerical score. As generators improve their scores, waste generation rates will be tracked to determine correlations in performance measurement and waste reduction. Subsequently, the associated cost savings and avoidances become apparent.

APPROACH

The ER Pollution Prevention Program assessed the existing planning techniques and practices. The major weakness found was the flowdown of pollution-prevention planning/practices into individual projects and tasks. To overcome the weaknesses and obstacles previously cited, an innovative approach is needed for implementing pollution prevention in all of the ER projects for all media. These needs are as follows:

- Development of a life-cycle model to aid in understanding how data are collected from various ER project phases;
- Use of computerized tools for generators to provide consistency in documentation of pollution-prevention and planning strategies.

- Brainstorming to conduct process waste assessments (PWAs) and establish quantitative performance measures;
- Development of numerical performance measure categories;
- Correlation of performance measurement and waste reduction for all environmental media; and
- Utilization of life-cycle costs developed from ER treatment, storage, and disposal modeling efforts to provide foundation for cost benefit analysis.

POLLUTION PREVENTION LIFE-CYCLE MODEL

The Pollution Prevention Program is a cyclic process with the objective of continuing to improve on previous results. The initial stage in the Pollution Prevention Program requires assurances that pollution-prevention plans are in place and that the development of a waste stream baseline has been initiated. The waste stream baseline, usually supported by a computer database, involves determinations of types of waste, volumes, toxicity, and other information for the various waste streams that will be generated. In the early stages of the model, a life-cycle approach has been integrated into the planning stages as shown in Fig. 1. Life-cycle costs are all costs associated with managing, treating, and disposing of any wastes or contaminants. These life-cycle costs are housed in a computer database. By using the numerical scoring system (NSS), waste generators can easily see which pollution-prevention techniques to use and which goals and objectives should be established. Opportunities identified during the waste assessment are then documented in the remedial investigation (RI) work plan. This is a very important step in the life cycle because it is the only way to ensure that subcontractors performing RI work implement waste-reduction techniques. The NSS is then used again to establish opportunities to minimize waste generation. Examples of opportunities for waste minimization during the typical RI include

- obtaining information through noninvasive techniques,
- reducing the number and size of bore holes,
- recycling decontamination water,
- reusing personal protective equipment (PPE),
- optimizing monitor-well locations, and
- implementing groundwater sampling procedures that minimize the volume of purge water.

The strengths and weaknesses of a pollution program are identified during the waste assessment stage. Strengths can include a well-conceived pollution-prevention plan and a strong management commitment to minimize waste production, thereby reducing the volume of waste generated during site investigations. Weaknesses may include insufficient attention to planning and failure to effectively implement the pollution-prevention techniques in the field. The RI work plan is compared to a generator checklist to make sure decontamination and decommissioning (D&D) pollution-prevention techniques are listed. The work plan is then implemented in the field by the subcontractor. After the RI project has been completed, the self-assessment program will determine

ORNL-DWG 93M- 2700 ER

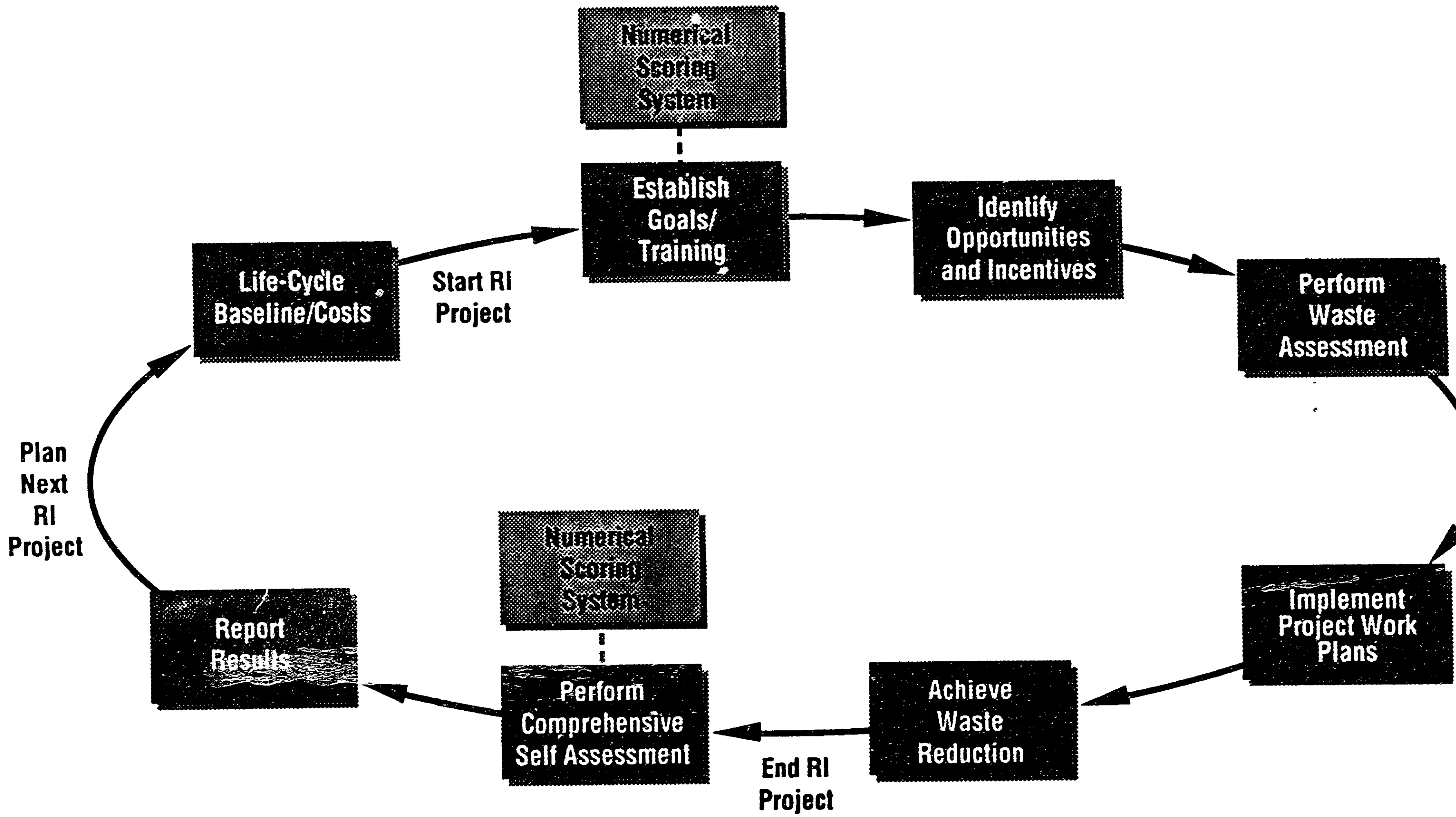

Fig. 1. Pollution prevention life-cycle model.

whether the reduction techniques employed are sufficient to meet the program goals by confirming actual versus planned estimates of production. These estimates can be further verified by program audits, and the information can be used to update the waste stream baseline. A formal, documented assessment program to monitor the pollution-prevention activities is considered an essential element of a successful Pollution Prevention Program.

The assessment system developed to support waste minimization for the ER Program is the NSS. The NSS can be effectively used to establish goals and objectives and also to monitor and rank pollution-prevention activities.

NUMERICAL SCORING SYSTEM

The NSS is a computerized, user-friendly information management system consisting of two tiers. The first tier is the database portion of the system, which is designed to maintain baseline data for the Pollution Prevention Program. The data is collected from input from waste generators. The database contains the facility-specific information and lists the waste-generating activities. The facility-specific information includes hazard characterization, regulatory status, volume, and project management costs for the various wastes at the subject facility. The waste-generating activities information includes the type and volume of wastes from these activities, the distribution of these wastes by regulatory status, and the total costs.

The second tier includes the system of algorithms for computing the individual indexes and the composite indexes for all of the waste streams. These indexes are designed to measure the effectiveness of different areas such as pollution-prevention general practice, waste-volume reduction, cost, and pollution prevention in the ER Program. The system design allows revision of the algorithmic parameters as data from implementing pollution-prevention techniques are assembled. The input-information tier of specific waste streams, waste-minimization techniques implemented, volumetric reductions achieved, and cost information. The output from this tier consists of the generator evaluation score (GES), a volume reduction index, a cost benefit index, and a relative ranking index.

DEVELOPMENT OF POLLUTION-PREVENTION TECHNIQUES ON IDW FOR RI

A planning checklist was developed to identify elements that should be considered for pollution prevention in the ER Program. The questions on the checklist are divided into two sections. The first section consists of general questions that apply to every phase of the program. These questions will be developed from the combination of the required elements in the Pollution Prevention Program and the elements of the Nuclear Quality Assurance document (NQA-1), which are relevant to waste minimization.

- Does the waste generator have a pollution-prevention plan incorporated in the RI work plan?
- Is the area of contamination clearly defined?
- Are the contaminants identified?

- What are the levels of contaminants?
- What waste streams will be generated?

After completing the assembly of general information, the waste generator is presented with a set of examples of remedial initiatives from which the waste generator picks the example that best illustrates the project of interest. The waste generator is then asked a series of yes or no questions dealing with specific elements of the generator's Pollution Prevention Program.

The second set of questions are phase specific and are developed from waste-reduction techniques for specific waste streams associated with the RI phase. These streams include soils, sediments, sludges, groundwater, decontamination liquids, and PPE. The questions are primarily used to collect waste-stream data and will be used to determine the total numerical score for the waste generator. The main purpose for the questions is to encourage the waste generator to (1) use the checklist to properly plan the project and (2) select appropriate pollution-prevention techniques during the planning effort.

The waste-stream questions were put into the Environmental Protection Agency (EPA) data quality objectives format to facilitate compliance with regulatory reporting requirements.

DEVELOPMENT OF POLLUTION-PREVENTION TECHNIQUES ON IDW FOR FS, D&D, AND S&M

As has been done previously for the RI phase, NSS questions will also be developed to evaluate the pollution-prevention plans for ER Program feasibility study (FS), D&D, and surveillance and maintenance (S&M) activities.

Questions on these new checklists will be divided into two sections. The first section will consist of general questions that apply to all phases of the ER Program. These questions will be based on the required elements in the ER Pollution Prevention Program and those elements of NQA-1 that are relevant to pollution prevention. The second section will be the waste-stream–specific section for each phase. These questions will be developed from waste-reduction techniques specifically used for different types of waste streams and will be specifically designed for FS, S&M, and D&D activities.

EVALUATION OF THE EFFECTIVENESS OF POLLUTION-PREVENTION ACTIVITIES

Presently, evaluation of the pollution-prevention activities for the ER Program is focused only on the RI projects in FYs 1993–1994 at the following DOE facilities: Y-12 Plant, K-25 Site, ORNL, Paducah, and Portsmouth.

GESs, volume reduction indexes, cost benefit indexes, and relative ranking indexes, as described in the following sections, are being used to evaluate various aspects of pollution-prevention activities specific to the RI projects at these facilities.

METHODOLOGY

The methodology for scoring the pollution-prevention activities for the RI projects from all six ER program sites (ORNL, K-25 Site, Y-12 Plant, Paducah, Portsmouth, and Clinch River/Off-Site) can be divided into the following three main steps:

1. Development of questionnaire and scoring mechanism.
2. Listing and selecting RI projects to be scored.
3. Application of questionnaire and scoring selected RI projects.

Using the developed RI checklist and the fully developed NSS, each site generator with a scheduled RI in FY 1993 or FY 1994 was asked to complete the questionnaires. The RI questions were grouped into six performance measures: training, self-assessment, field implementation, documentation, technology transfer, and planning. The answers obtained from the generators were scored using the algorithms developed in the NSS.

Numerical scores from the generators were based on a composite of general and waste-stream questions. The general questions were made up of yes/no and multiple choice questions. The waste-stream questions were made up of yes/no and fill in the blank questions.

GENERATOR EVALUATION SCORE

The GES component of the NSS system is an interactive, computer-screen-based questionnaire derived from applicable NQA-1 elements, data quality objectives (DQOs), and successful pollution-prevention programs. The questionnaire is designed to provide guidance to the user concerning incorporation of the necessary waste-reduction elements during the implementation of projects. This component of the system will consist of a set of inquiries derived from the 18 elements of NQA-1 and eight EPA elements. Figure 2 is an illustration of the correlation of waste-minimization program requirements and the NQA-1 elements applicable to the ER Program phases.

VOLUME REDUCTION INDEX

The volume reduction index is intended to measure the effectiveness of the waste generator's efforts to achieve significant volume reduction. A numerical index, S, is defined as the effectiveness of the pollution-prevention efforts for volume reduction. The value of S is determined through a comparison of the actual volume reduction achieved to the potential reduction. For a given waste stream, j, the mathematical representation of S_j is:

$$S_j = \frac{A_j}{R_j} , \qquad (1)$$

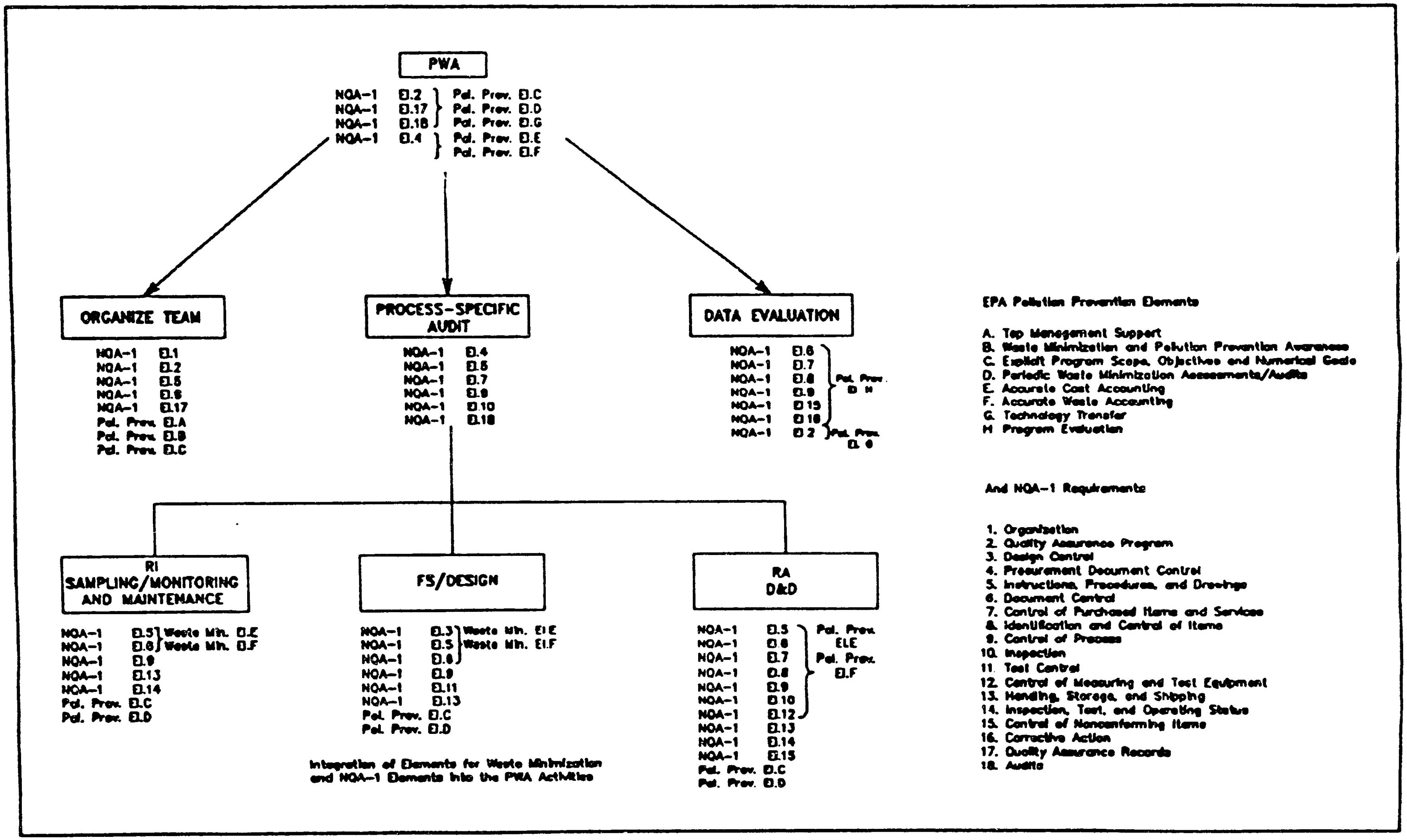

Fig. 2. Environmental Protection Agency pollution prevention elements and NQA-1 requirements.

where S_j is a numerical index that measures the effectiveness of waste-minimization efforts as related to volume reduction for waste stream j, A_j is the actual volume reduction index for waste stream j, and R_j is the potential reduction index for waste stream j (details of indexes A_j and R_j will be described in later sections).

It is likely that during early implementation of the NSS cases will occur in which the value of the ratio will exceed 1.0 as a result of techniques or gains not considered in the initial development stage. Therefore, data concerning these situations will be used to interactively refine the parameters used to calculate the potential reduction index.

The actual volume reduction index, A_j, is the ratio of the actual volume reduction achieved by the implementation of waste-minimization techniques to the total volume that would have resulted without waste-minimization efforts. This is mathematically represented as:

$$A_j = 10 \times \frac{(V_{jp} - V_{ja})}{V_{jp}} , \tag{2}$$

where V_{jp} is the volume of waste stream j that would be generated without implementing any waste-minimization techniques, V_{ja} is the volume of waste with the implementation of waste-minimization efforts, and A_j is the volume reduction index for waste stream j (A_j would have a value in the range of 0 to 10).

The potential reduction index, R_j, is designed to measure the theoretical volume or toxicity reduction achieved by a given waste-minimization technique. The potential reduction index, V_{ij}, for a waste stream j and reduction technique i is:

$$r_{ij} = \frac{e_{ij} \times P_{ij}}{10} , \tag{3}$$

where r_{ij} is the reduction index for waste stream j using the reduction technique i (maximum value of 10), the value e_{ij} is the effectiveness of reduction technique i on waste stream j (range of 0 to 10), and P_{ij} is an adjusted value of the probability of reduction technique i being implemented for waste stream j.

Estimation of the effectiveness and probability parameters will be developed for each target waste-stream and reduction technique by doing literature searches and using the best engineering judgment.

After determining the potential reduction index for each waste-stream and reduction technique combination, the composite potential reduction index , R_j, for waste stream j will be calculated. It is considered unlikely that the entire range of reduction techniques could be applied to a given waste stream. Therefore, the composite-reduction index for the waste stream will be based on only those techniques that are considered to be most favorable.

COST BENEFIT INDEX

The cost benefit index provides a cost benefit factor that will enable the waste generator to assess the economic effectiveness of a particular waste-minimization technique. The cost benefit index is the ratio of the overall cost saving from implementing waste minimization to the overall cost of managing the waste without minimization efforts. This cost benefit index for a waste stream *j* can be represented as:

$$C_{ja} = \frac{C_j - C_{jm}}{C_j} \,, \qquad (4)$$

where C_{ja} is the cost benefit index for waste stream *j* (maximum value of 1), C_j is the overall cost of managing the waste without waste minimization, and C_{jm} is the cost of managing the waste with minimization of waste stream *j*.

RELATIVE RANKING INDEX

The relative ranking index is a measure of the desirability of the implemented minimization efforts relative to the pollution-prevention hierarchy. The relative ranking index for a given technique and waste stream may be defined by the pollution-prevention hierarchy factor, Z_{ij}, in conjunction with the effectiveness factor, e_{ij}, as represented by the following equation:

$$h_{ij} = \frac{e_{ij}\, Z_{ij}}{10} \,, \qquad (5)$$

where e_{ij} is the effectiveness of reduction technique *i* on waste stream *j* (maximum value of 10), Z_{ij} is the pollution-prevention hierarchy of reduction technique *i* being implemented for waste stream *j* (value range from 0 to 10), and the parameter h_{ij} is the relative ranking index of reduction technique *i* on waste stream *j*.

FUTURE SCORING MECHANISM

A periodic reevaluation of the pollution-prevention activities in the ER Program will be very beneficial. The reevaluation will not only give a better picture of how well each individual generator and the overall program are doing, but it will also facilitate feedback of the necessary information to the NSS, which is by nature a dynamic process.

Some indexes, such as the volume reduction index and the relative ranking index, will greatly benefit from a frequent reevaluation because these indexes are designed for long-term self-refinement. Parameters used in the calculations will need a series of iterations to improve accuracy. The cost benefit evaluation will also improve with the maturity of the pollution-prevention activities in the ER Program. The breakdown in cost accounting will get better, and in turn, more detailed cost information will become available. This will result in a more accurate definition of the cost benefit index.

The waste generator will also be provided with outputs for documenting all performance indexes that include their GES answers, volume reductions, cost benefits, and relative ranking.

SCORING FOR FS, D&D, AND S&M PHASES

The initial stage of development of the FS, D&D, and S&M checklist questionnaires has just begun. The preliminary questionnaires will serve as the pilot stage of the evaluation of the pollution-prevention activities in the FS, D&D, and S&M phases. Eventually, a full-scale scoring mechanism will be developed to serve as an evaluative tool for waste generators in these phases. It is likely that the scoring mechanism and index already developed for the RI phase in the NSS, with some adjustment to accommodate the different nature of FS, D&D, and S&M phases, will be used as an evaluative tool for these three phases.

PERFORMANCE MEASURE DEVELOPMENT

The following section is a summary of the findings from performance measure categories based on the K-25 Site ER Program and the other ER programs concerning field implementation. Figure 3 is an illustration of how the K-25 Site scored by category. Other performance measure sites include the Oak Ridge Y-12 Plant, the Oak Ridge National Laboratory, the Portsmouth Uranium Enrichment Complex, the Paducah Gaseous Diffusion Plant, and the Clinch River/Off-Site facility. These performance measure results are illustrated in *Environmental Restoration Program Pollution Prevention Performance Measures for FY 1993 and 1994 Remedial Investigations* (ES/ER/TM-59).

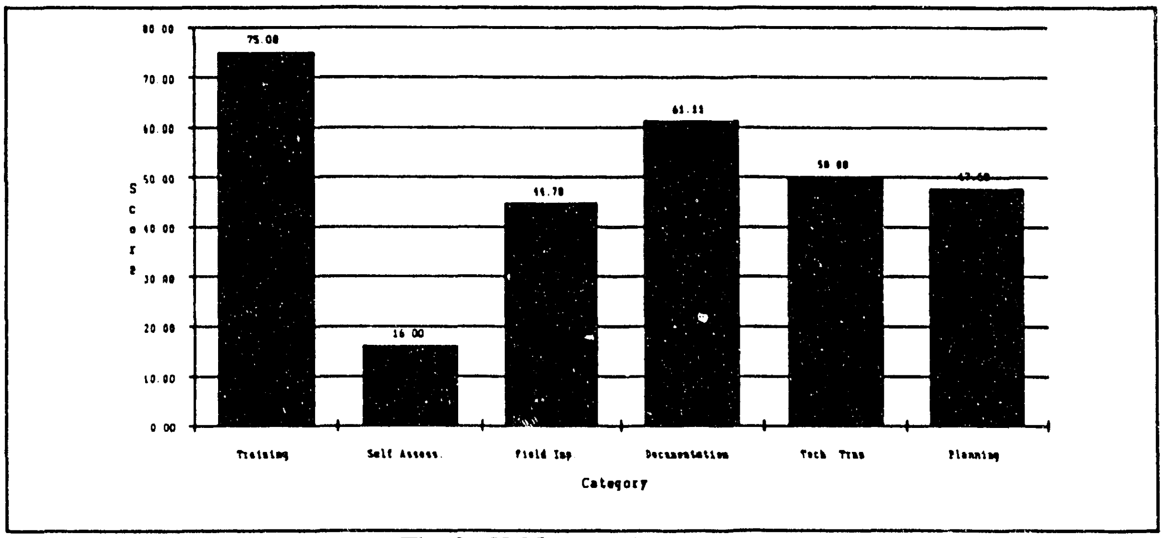

Fig. 3. K-25 scores by category.

K-25 SITE ER PROGRAM

The K-25 Site ER Program exceeded the requirements in the training category (Fig. 3). This program needs improvement in the field implementation and planning categories. The program needs corrective action in the self-assessment audit category.

FIELD IMPLEMENTATION

All ER programs received a need improvement rating for this performance category (Fig. 4). This is primarily attributed to program managers not being intimately involved with the details of waste handling and waste management.

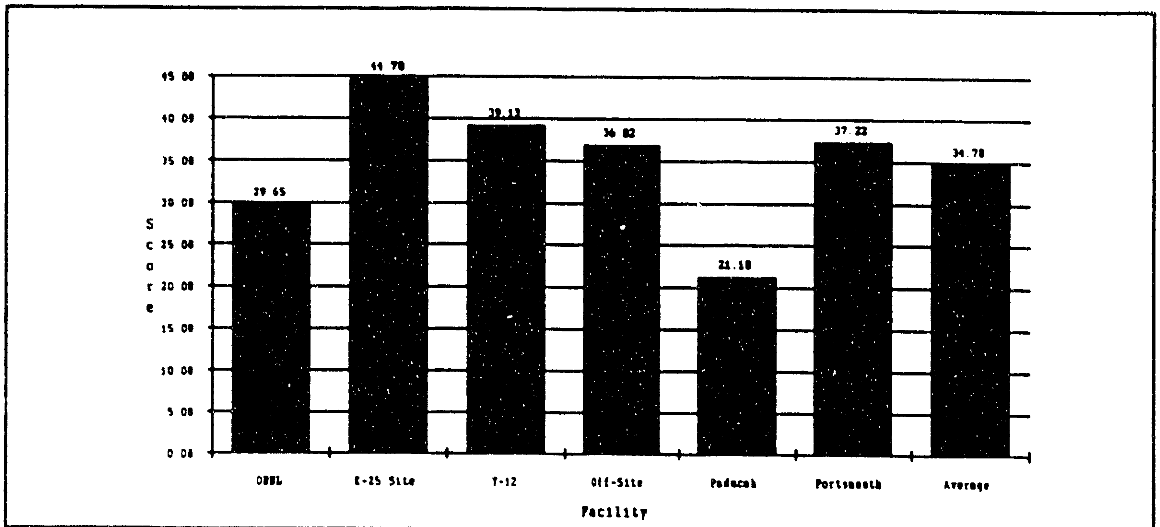

Fig. 4. Field implementation scores by facility.

CORRELATION OF PERFORMANCE MEASURES WITH WASTE-VOLUME REDUCTION

When adopting a scoring system to aid in achieving waste-volume reduction, consider how performance-measure data impact the rate of waste generation, then express this relationship numerically. The author acknowledges that the accuracy of this infant numerical correlation model is questionable; thus, it is a good starting point.

The numerical correlation model that proposes three scenarios from which volume reduction will be determined is presented in Fig. 5. The top curve is the projected volume in cubic feet and represents a performance rating of zero (i.e., without pollution prevention/ waste minimization). The middle curve is the potential volume estimate and represents an overall performance rating of "Meets the Requirements" (i.e., a score of 50–69). The bottom

ORNL-DWG 93M-2713 ER

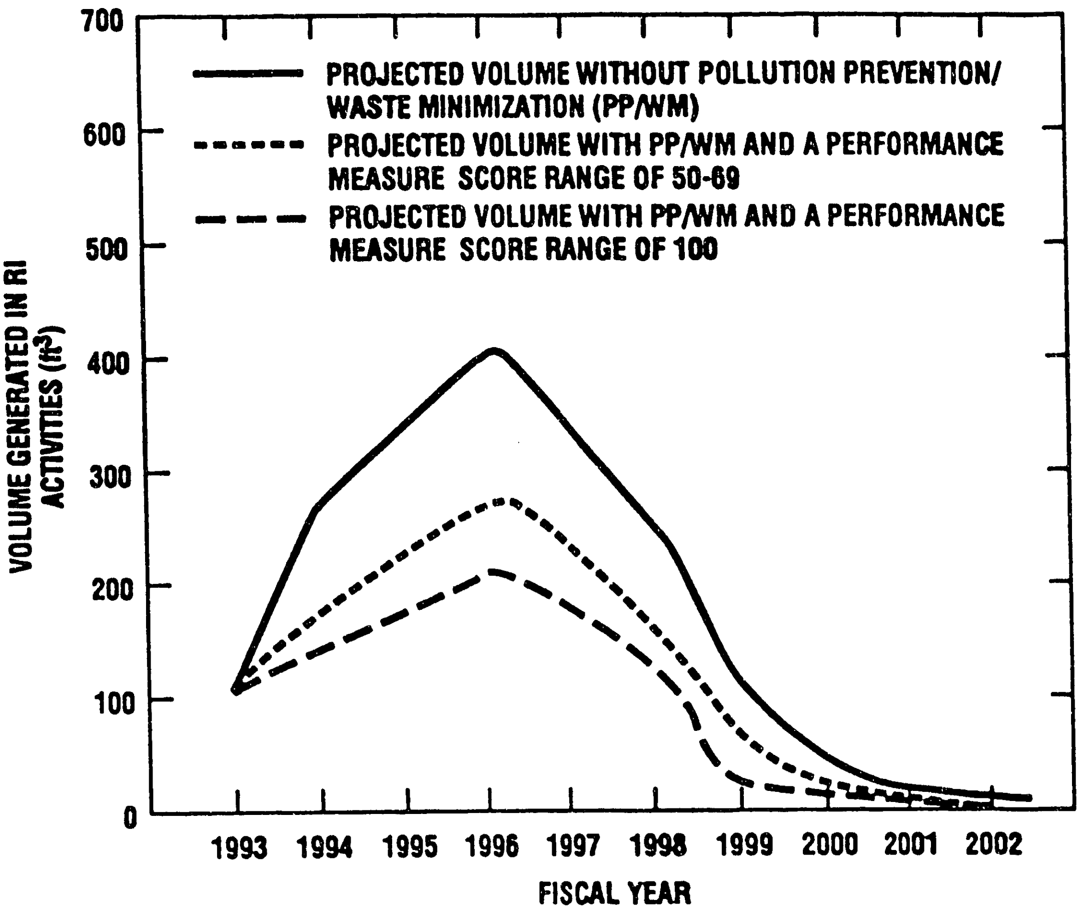

Fig. 5. Numerical correlation model.

curve is the potential volume estimate and represents an overall performance rating of "Perfect Score" (i.e., a score of 100). The middle and the bottom potential-volume-estimate curves were derived from the volume-reduction-index formula, which was presented in the Numerical Scoring System section of this paper. The criteria used to calculate the potential volume estimate is presented in Fig. 6.

Before the start of each RI project, waste generators utilize the NSS to assess themselves on their planning and implementation of pollution-prevention techniques through numerical scoring. Their numerical scores are then distributed into the six performance measure categories. Waste generators can improve their performance-measure scores by setting quantitative performance goals, performing PWAs, selecting and implementing pollution-prevention techniques in their work plans, and identifying and correcting deficiencies.

At the completion of each RI project, waste generators again utilize the NSS to actually assess their improvement. Their actual waste generation of IDW can be compared to their potential volume estimates to determine if waste reduction was achieved.

1. Performance measure score is influenced by	a. general question scores b. relative ranking scores, which $= \frac{e_{ij} \times z_{ij}}{10},$ where z_{ij} = Hierarchy factor e_{ij} = effectiveness
2. Volume reduction can be calculated using	volume reduction index $= \frac{e_{ij} \times p_{ij}}{10},$ where e_{ij} = effectiveness p_{ij} = probability
3. Correlation of performance level score and volume reduction index is through	e_{ij}
4. *For Perfect Score of PM.* Relative Ranking = 100, *eij* and *zij* each = 10	a. calculate volume reduction index that *all* e_{ij} *=10* b. assume that there are 1.5 reduction technique use for each waste stream c. evaluate total sum reduction
5. *For "Meet the Requirement" of PM.* Relative Ranking = 50–69	a. calculate volume reduction index that e_{ij} is in the range (5.0–6.9). This is the average range of e_{ij}. b. assume there is 1.0 reduction technique used for each waste stream. c. calculate total-volume reduction
6. Assume that it takes 1 year to implement	waste minimization/ pollution prevention to see any decrease in volume

Fig. 6. Criteria used to calculate potential volume estimate.

POLLUTION PREVENTION LIFE-CYCLE COST MODEL

A key step in performing cost benefit analyses to prioritize PWAs is the integration of the NSS with the Treatment, Storage, Disposal (TSD) Capacity Model. The objective with the TSD capacity model is to integrate waste-generation forecasting with TSD planning to provide a forecast of ER Program facility needs.

The TSD capacity planning basis (Appendix B of the DOE Oak Ridge Field Office Environmental Restoration Program Waste Management Plan) contains waste-stream logic diagrams from model scenarios that summarize the major waste-handling steps in the life cycle. In addition, there are costs associated with each waste-handling step commonly known as life-cycle costs (i.e., all costs of managing, treating, and disposing of any wastes or residuals).

By integrating the NSS with the TSD model, the waste generator acquires the capability to perform cost benefit analysis. With waste-generation forecasts, life-cycle costs, and general facility information integrated, the NSS could possibly aid the waste generator in performing cost benefit analyses with output information similar to Fig. 7. Of course, the expectation of this exercise is to identify potential cost savings, prioritize waste streams to conduct PWAs, and recognize opportunities for cost avoidances.

RECOMMENDATIONS AND CONCLUSIONS

After reviewing the information obtained in this project, it can be concluded that the area of multimedia waste-reduction performance measurement is very complex. In observing DOE sites and various private vendors, it was discovered that most generators are trying to measure their waste reduction after the generation of the waste. This is perhaps the normal method of measuring waste minimization, but it does not give accurate results in all cases, especially for remedial or restoration activities.

Until accurate waste generation and life-cycle cost data are available, it is concluded that use of common pollution-prevention measures such as percentage goals for ER would not yield meaningful results. Pollution prevention is a high priority because of regulatory drivers and costs benefits; therefore, it is imperative that we apply meaningful performance measures.

In conclusion, a multimedia approach to performance measures that accurately reflect the steps taken to prevent pollution and to minimize multimedia transfers and reduce waste is essential to the ER Program. One of the first steps in this approach is the application of the Pollution Prevention Life-Cycle Model. The model, which is based on a cyclic process, is designed to collect trend data from the various phase projects to be measured. The next step is to use the NSS, which scores a waste generator on how well they are implementing the best methods available to maximize pollution prevention.

ORNL-DWG 93M-2714 ER

LIFE-CYCLE WASTE	LIFE-CYCLE COST	CUMULATIVE	WITH PWA LIFE-CYCLE COST[a]	CUMULATIVE COST	COST SAVINGS
PLANNING			39,000	39,000	
GENERATE[b]					
PACKAGE ($10/ft³)	100,000	100,000	90,000	129,000	10,000
CHARACTERIZE ($2/ft³)	20,000	120,000	18,000	147,000	2,000
STORAGE ($5/ft³/ year for 2 years)	100,000	220,000	90,000	237,000	10,000
CHARACTERIZE	20,000	240,000	18,000	255,000	2,000
TREATMENT[c] ($50/ft³)	500,000	740,000	450,000	705,000	50,000
STORAGE (1/year)	67,500	807,500	60,750	765,750	6,750
DISPOSAL ($100/ft³)	1,350,000	2,157,500	1,215,000	1,980,750	135,000
TOTALS	$2,157,500	$2,157,000	$1,980,750	$1,980,750	$215,750

[a]*Assume a Generation of 10,000 ft³ of RCRA/TSCA/Mixed Waste*
[b]*Assume a 10% Waste Reduction (9,000 ft³)*
[c]*Assume a 35% Volume Expansion*

Fig. 7. Model life-cycle cost.

Although the NSS is in the premature stages of development, Energy Systems and other environmental cleanup site managers will be able to realize the following benefits of pollution prevention in every aspect of remedial-action planning and project implementation.

- Multimedia performance measurement is very complex.
- Limited dollars will be needed to implement because personal computers are readily available.
- Performance indexes for pollution-prevention activities will be established.
- Cost savings will result as waste generators train and assess themselves, eliminating expensive PWAs and audit teams.
- Follow-up on the NSS of RI projects is recommended in the next 12 to 18 months.
- NSS performance measure goals should be established by ER Program sites as a target for each performance measure.
- Lessons that are learned should be used in the numerically scored generators in FYs 1995 through 1996.
- Improvements are being planned for the questionnaire.
  —training and technology transfer categories of the questionnaire will be revised.
  —some categories of the questionnaire such as self-assessment will contain fewer questions.
- Process waste assessment methodology and documentation should be incorporated into the NSS.
- Incentives for generators must be in place.
- Waste generators will be given consideration if they have minimized waste before scoring the NSS.
- Input should be sought from waste generators in the early planning stages of scoring.
- Improvements in communication between ER personnel and plant management personnel will better facilitate pollution prevention activities.
- Performance measures should be correlated with projected vs actual waste generation.
- Numerical scoring concept will be expanded into the S&M, FS, and D&D ER phases.

BIBLIOGRAPHY

Benforado, D. M., "Corporate Transition to Multimedia Waste Reduction Measuring Waste Reduction Progress in The Environmental Challenge of the 1990s," *published in Proceedings of International Conference on: Pollution Prevention: Clean Technologies and Clean Products June 10–13, 1990,* pp. 48–56.

Defense Cleanup Newsletter, Vol. 3, No. 35, December 4, 1992, page 1.

DOE Oak Ridge Field Office Environmental Restoration Program Waste Management Plan, DOE/OR-976, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, Appendix A, Rev. 1, October 30, 1992, page A-7.

Grumski, J. T., *Revised Investigation-Derived Waste Management Plan*, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, June 26, 1992.

Grumski, J. T., B.E. Phifer, Jr., *TSD Capacity Model Interface with Waste Reduction Planning in the Environmental Restoration Program*, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Facility Pollution Prevention Guide, U.S. Environmental Protection Agency, EPA/600/R-92/088, Office of Research and Development, Washington, DC, May 1992.

Phifer, B. E., Jr., *Environmental Restoration Program Process Waste Assessments (PWAs), "Pay Now or Pay More Later,"* Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, prepared for the Waste Reduction Conference, March 1992.

Podar, Dr. Mahesh K., Integrated Permits and Multimedia Pollution Prevention, *Proceedings of International Conference on: Pollution Prevention: Clean Technologies and Clean Products June 10-13, 1990,* pp. 520-527.

Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, *Environmental Restoration Program Waste Minimization and Pollution Prevention Awareness Program Plan*, ES/ER/TM-21 prepared by Science Applications International Corporation, September 1991.

Miller, J. Q., T. Hale, and D. Miller, *Methodology for Generating Waste Volume Estimates*, ES/ER/TM-18, Environmental Restoration Program, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, September 1991.

"Turning Compliance Costs into Production Opportunities," *The American Society of Mechanical Engineers*, February 26, 1992.

U.S. Department of Energy, DOE Order 5400.1, "General Environmental Protection Program," November 9, 1988.

U.S. Department of Energy, DOE Order 5400.3, "Hazardous and Radioactive Mixed Waste Program," February 22, 1989.

U.S. Department of Energy, DOE Order 5820.2A, "Radioactive Waste Management," September 26, 1988.

U.S. Department of Energy, Formerly Utilized Sites Remedial Action Program (FUSRAP), *Waste Minimization and Pollution Prevention Awareness Plan*, June 1991.

U.S. Department of Energy, *Model Process Waste Assessment Plan*, January 1991.

END

DATE
FILMED
8 / 18 / 93