METHODOLOGY FOR DEVELOPMENT OF ENVIRONMENTAL STRATEGIC MANAGEMENT PLAN FOR INDUSTRIAL FACILITIES WITH CONTAMINANT RELEASES

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ABSTRACT: This paper presents a technique for developing an optimized environmental strategic management plan for facility multi-media contaminant releases. The technique is used for developing a strategic management plan in the early investigation phases (of the RCRA Corrective Action Process) for a contaminant release from a facility based on the (usually) limited and incomplete data available in the early investigation stages.

The resulting strategic management plan is used as a basis for preliminary budgeting and risk management planning and is updated as investigation and pilot test data for the site are obtained.

An example of the use of the technique has provided an evaluation of the general environmental, regulatory, and business risk for a refinery facility. The resulting strategic management plan can prioritize the environmental parameters of concern, prioritize the expected points of compliance, and give an estimate of the variation of the key parameters and of the resulting remediation duration and cost.

The technique provides a mechanism for identifying the dominant remediation alternatives. It provides a preliminary plan, based on limited available data, for the framework of the preferred alternatives for managing the releases of a site. The technique also provides a basis for updating the plan as data is obtained from site investigation activities, pilot tests, and remediation.

A Monte Carlo simulation of the sequential decision process involving key contaminant-specific parameters, remediation alternatives, site-specific parameters, and regulatory requirements provides quantitative evaluation of the objectives, the variability of the key parameters affecting the objectives, and the sensitivity of the objectives to variations in key parameters.

The results of the effort provides the owner with a quantitative approach to prioritizing the environmental concerns of the facility release from both technical and business perspectives.

General Background

The Environmental Strategic Management Plan Decision Support System (DSS) is a software package comprised of several modules which together model investigation and remediation activities of the (RCRA) corrective action process for a specific site or for a facility with multiple sites.

The DSS uses a probabilistic representation of key data parameters which allows development of the baseline plan using limited or incomplete data. A probabilistic approach makes the best use of available information because key data parameters are expressed as known or estimated probability distributions rather than a single number which is the deterministic approach.

Endpoints of the modelling process can include any or all of the following.

- A probabilistic distribution of the estimated mass of specific contaminants by phase (i.e., vapor phase, phase separated, absorbed phase, and dissolved phase)
- A probabilistic distribution of the estimated duration to remediation for specific contaminants

and phases using specific technologies

- A baseline schedule of prioritized activities of the selected remediation strategy

- A probabilistic distribution of the cost estimate corresponding to the selected remediation strategy

- A spreadsheet of projected cash flow corresponding to the mean values of the remediation duration and cost estimate for the selected remediation strategy

This probabilistic modelling allows establishment of a planned baseline of prioritized activities using existing data. As the prioritized site investigation activities are executed, the DSS can be used to update the baseline or to perform sensitivity analysis for alternative scenarios.

Methodology

The DSS is comprised of a model which simulates the RCRA Corrective Action Process for a particular Solid Waste Management Unit (SWMU) or Corrective Action Management Unit (CAMU).[1] Figure 1 - RFI/RCRA Corrective Measures Process is a flow diagram of the general corrective action process for a specific unit.

The model facilitiates prioritizaton of activities for various Solid Waste Management Units (SWMUs) or Corrective Action Management Units (CAMUs) or Temporary Units (TUs) which may be in dissimilar stages of the Corrective Action Process.

Typically, multiple units at a facility will be in various stages of the corrective action process. By generating projected remediation durations and costs for specific media and contaminants for individual units (SWMUs or CAMUs) the results can be superimposed to indicate total remediation projections and costs for the facility as a whole.

The model formulation requires (1) characterizing key parameters, (2) delineating a set of constraints, and (3) defining objective function(s).[2] These are explained below.

Key Parameter Characterization

The characterization of the contaminants and the associated release unit parameters is performed as in any typical waste and unit characterization.[3] The DSS uses a contaminant mass balance approach producing estimates of contaminant mass by phase (media). These estimates are produced for individual contaminants

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1 RCRA Facility Investigation (RFI) Guidance, Volume I of IV, Development of an RFI Work Plan and General Considerations for RCRA Facility Investigations, Interim Final, EPA 530/SW-89-031, May 1989, Waste Management Division, Office of Solid Waste, U.S. Environmental Protection Agency, pp. 2-1 through 2-26.

2 Management Science, by Terry L. Dennis and Laurie B. Dennis, West Publishing Company, 1991, pp. 348-369, pp. 591-612, and pp. 722-730.

3 RCRA Facility Investigation (RFI) Guidance, Volume I or IV, Development of an RFI Work Plan and General Considerations for RCRA Facility Investigations, Interim Final, EPA 530/SW-89-031, May 1989, Waste Management Division, Office of Solid Waste, U.S. Environmental Protection Agency, pp. 7-1 through 7-23.

which appear to be above action levels concentrations within the pertinent media.

Formulation of Constraints

Figure 2 - Strategic Management Decision Support System Execution diagram is a flowchart identifying the principal steps in identifying and characterizing statistically the primary site-specific parameters relating to phase-specific contaminant masses. The model itself consists of a Monte Carlo simulation of the Corrective Action Process including remediation technology selection and projected remediation durations and costs.

The constraints are derived from three site-specific considerations. These three site-specific considerations are:

- Regulatory Constraints
- Technology Constraints
- Business Constraints

These constraints are obviously not mutually exclusive for all specific sites. For example, a regulatory constraint to perform Interim Corrective Measures would indicate specific technologies which would be required to meet the ICM objectives. This technology, or technologies, might be to facilitate hydraulic control and/or might result in the reduction of specific contaminant mass in one or more of the media-specific phases.

Regulatory Constraints

Regulatory constraints may be explicit for the site or implicit through established regulatory procedures and guidelines. Explicit site-specific constraints include such things as an agreed Interim Corrective Measure or an accelerated cleanup of a targeted contaminant due to concerns about potential sensitive receptors.

Implicit regulatory constraints include such things as regulator-established cleanup levels for contaminants which are usually the starting point for evaluating projected remediation potential.

Determining the target cleanup level is a key element of the DSS because the target cleanup level determines how much contaminant is left behind after remediation (the residual contaminant mass). The contaminant mass to be remediated is the difference between the mass calculated from site data and the residual contaminant mass.

Target cleanup levels may be determined initially using simplified exposure scenarios and standard exposure assumptions, e.g., direct exposure of on-site workers to surface soil at maximum exposure (RMI) level as prescribed by EPA. By setting a target risk level for carcinogens and a target hazard index for noncarcinogens the target cleanup levels are calculated using simple algorithms that may be inserted into the DSS as a separate module. Cleanup levels may be determined in this simplified manner for the baseline plan, but this does not replace the baseline health risk assessment which should be included as an integral part of the corrective action process. Refined and/or negotiated cleanup levels can be inserted into the DSS when they become available.

Technology Constraints

Technology constraints can be represented through parameters in the modelling process such as projected media-specific contaminant removal rates. Conventional technology experience, especially previous remediation experience at similar sites, is the most likely source of data for parameters such as contaminant removal rates.[4,5,6,7]

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4 Groundwater Treatment Technology, by Evan K. Nyer, Van Nostrand Reinhold, 1985, pp. 2-83.

Business Objectives

Business objectives can be significant in selecting from feasible remediation strategies. Some examples of business objectives which would affect the selected strategy are minimum cash flow over the period of remediation, minimum cleanup time, and minimum capital cost. In some cases, where the feasible remediation strategies do not produce a clearly preferred strategy, the probabilistic approach can be used to select a remediation strategy or "short-list" of feasible strategies. Then a goal programming approach to linear programming can be used to analyze situations which have complex multi-objective scenarios.[8,9]

Formulation of Objective Function(s)

The objective functions are defined based on considerations of the above various site-specific constraints and upon Owner/Operator's business objectives for the facility. These business objectives may vary from site to site and may even vary for a particular site over time. Some examples of objective functions for a specific site follow.

- Minimum cash flow per period over the duration of the projected remediation at the site
- Minimum total cost of investigation and remediation based on discounted net present value
- Minimum duration of remediation
- Maximum removal rate for specific contaminant(s)
- Minimum capital requirements for remediation alternatives

The outputs of the DSS (e.g., projected remediation durations for various contaminants and media, projected costs for alternatives, etc.) are evaluated with respect to the objective functions and preferred alternatives are selected. The probabilistic results provide parameters such as mean values and standard deviations of the key decision parameters (duration, cost, etc.,) from which alternatives can be ranked.

Attachment A includes some examples of output from the model.

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5 Hazardous Waste Site Remediation: The Engineer's Perspective, Robert Bellandi, Technical Editor, Van Nostrand Reinhold, 1988, pp. 255-316.

6 Evaluation of Remedial Action Unit Operations at Hazardous Waste Disposal Sites, by John Ehrenfeld and Jeffrey Bass, Noyes Publications, 1984, pp. 13-57 and pp. 215-390.

7 Halogenated-Organic Containing Wastes – Treatment Technologies, by N. Surprenant, T. Nunno, M. Kravett, and M. Breton, Noyes Data Corporation, 1988, pp. 376-395.

8 Linear Programming in Single- and Multiple-Objective Systems, by Ignizio, James P., Prentice-Hall, 1982, pp. 372-391.

9 Managerial Decisions Under Uncertainty, by Bruce F. Baird, John Wiley and Sons, Inc., 1989, pp. 418-446.

Figure 1. RFI/RCRA Corrective Measures Process

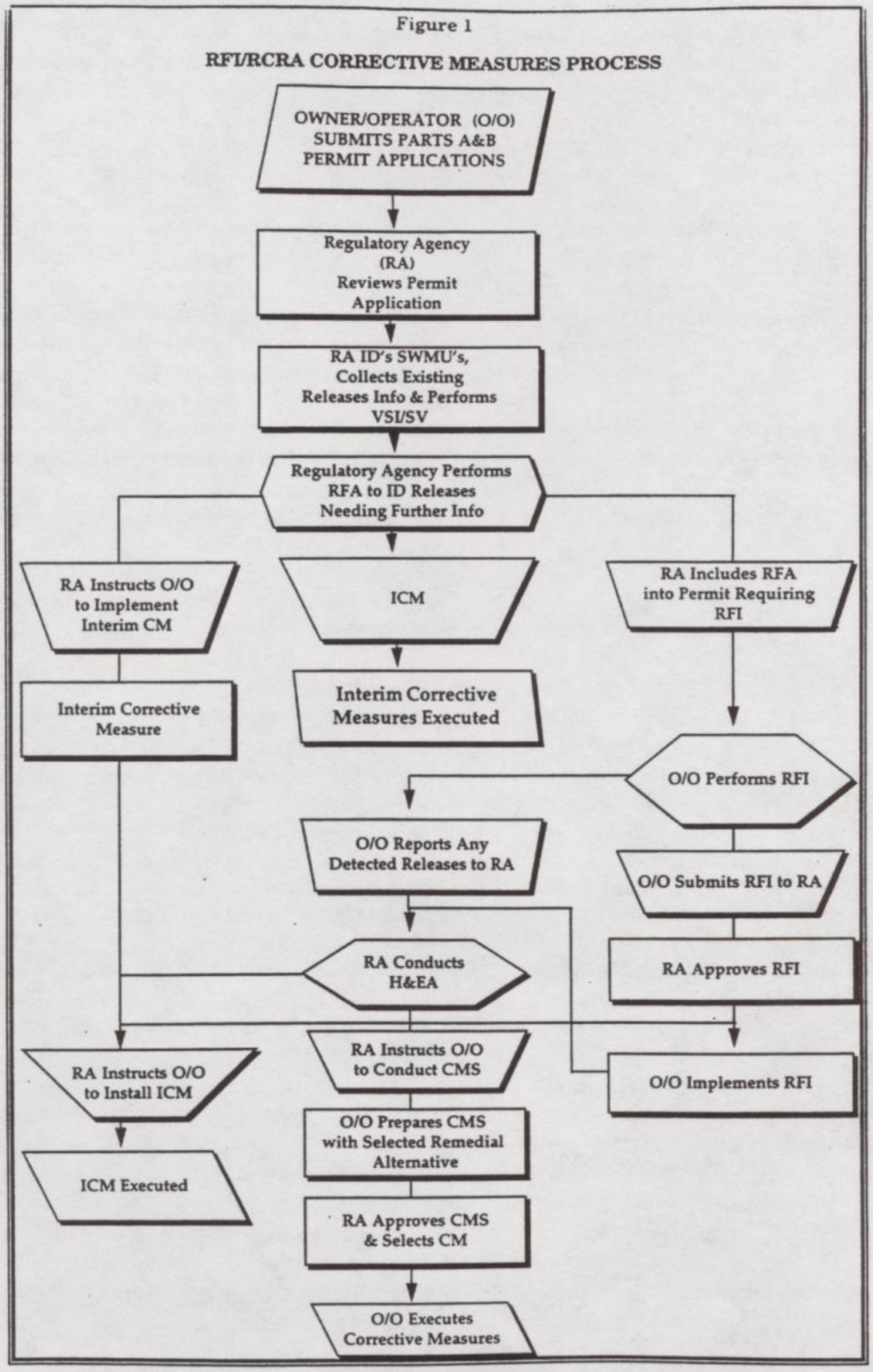


Figure 2. (Page 1) Strategic Management Decision Support System Execution Flowchart

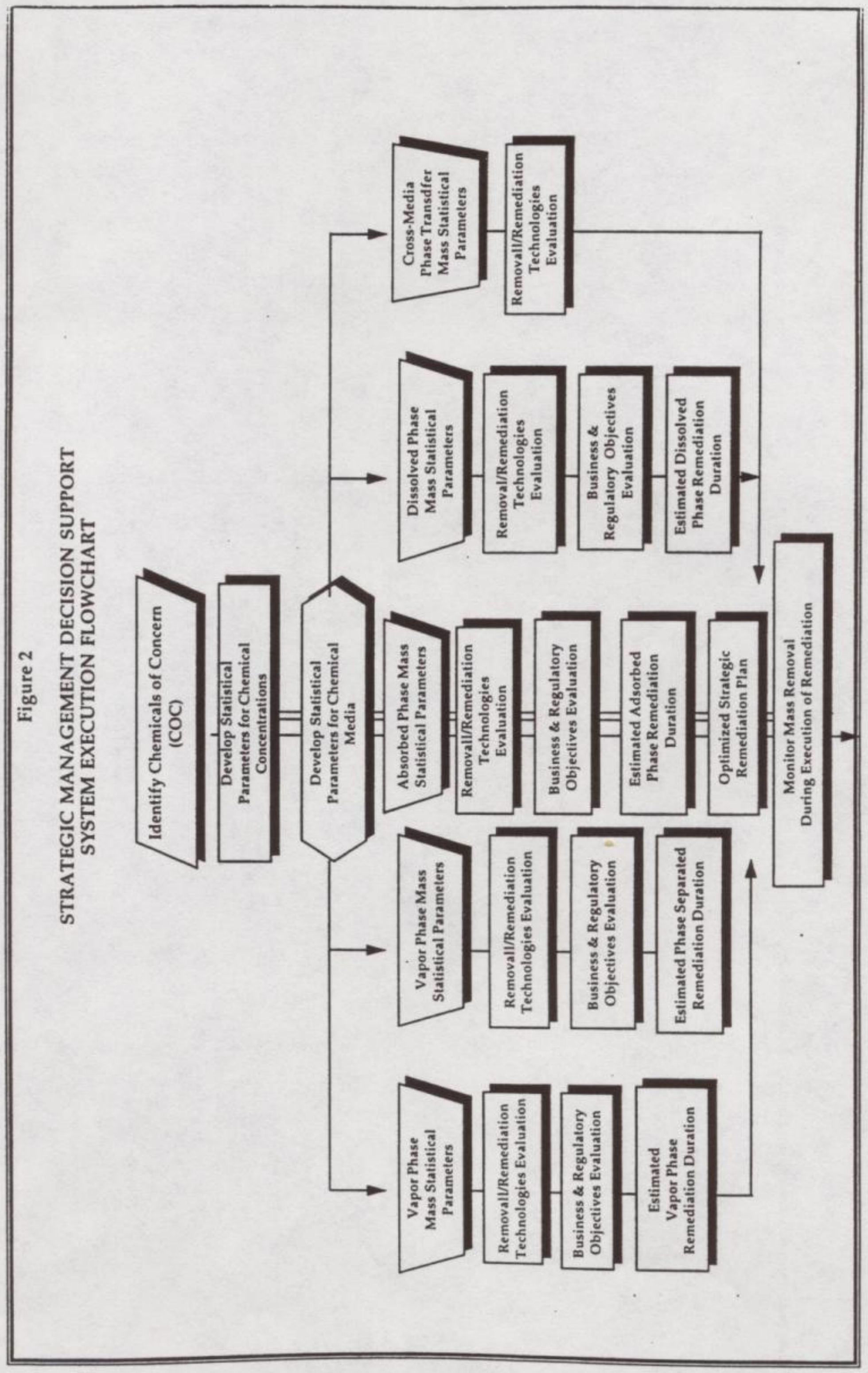
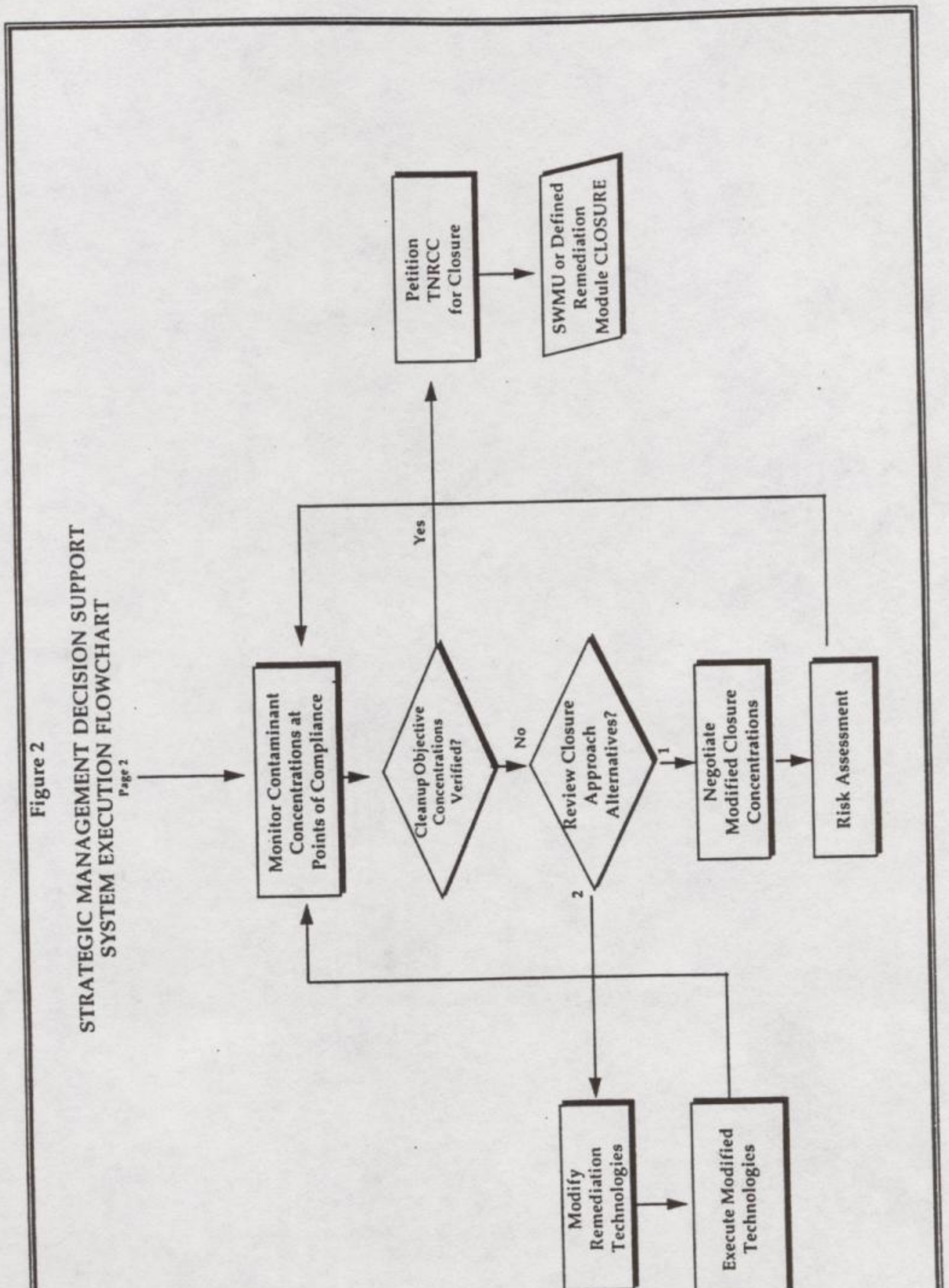


Figure 2 (Page 2)



ATTACHMENT A

EXAMPLE OUTPUT FROM DECISION SUPPORT SYSTEM

The following five pages contain attachments of charts/tables/figures

ENVIRONMENTAL STRATEGIC MANAGEMENT PLAN – WORKSHEETS

DISSOLVED PHASE

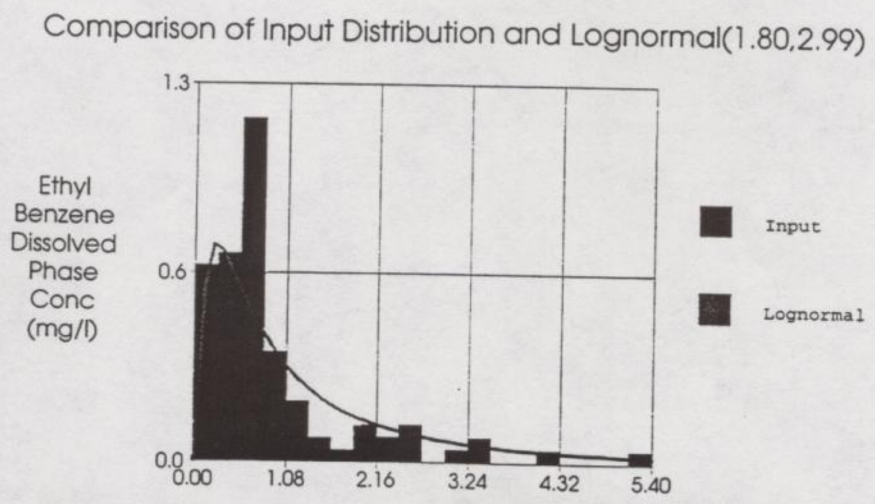
CLIENT:
PROJECT:

EMCON INDUSTRIAL ENVIRONMENTAL SYSTEMS – HOUSTON

ESTIMATED CONTAMINANT MASS
AND
ESTIMATED CONTAMINANT MASS REMEDIATION DURATION
WORKSHEETS

Dissolved Phase:

#	Contaminant	CAS #		Zone	Detected Groundwater Concentration Distribution (mg/L)	Horizontal Area Distribution (m2)	Average Dissolved Phase Thickness Distribution (m)	Effective Porosity Distribution	Estimated Water Volume Distribution (m3)	Estimated Contaminant Mass Distribution (kg)	Contaminant Type	(MCL) MSC GW (mg/L)	Mass Removal Rate (kg/month)	Estimated Remediation Duration (months)	Estimated Remediation Duration (years)	Estimated Remediation Cost
1	Benzene	71-43-2	A	A	5.78E+00	8.95E+05	15	0.20	2,684,836	1.55E+04	VOC	5.00E-03				
				B												
				C												
				D											B-GW-AY	B-GW-ACT
								TOTAL		1.55E+04	B-GW-AM		4.74E+01	327	27	$5,451,831
2	Ethylbenzene	100-41-4		A	1.80E+00	8.95E+05	15	0.20	2,684,836	2.95E+03	VOC	7.00E-01				
				B												
				C												
				D											E-GW-AY	E-GW-ACT
								TOTAL	2,684,836	2.95E+03	E-GW-AM		1.48E+01	200	17	$4,230,118
3	Xylene	1330-20-7	D	A	8.85E+00	8.95E+05	15	0.20	2,684,836	0.00E+00	VOC	1.00E+01				
				B												
				C												
				D											X-GW-AY	X-GW-ACT
								TOTAL	2,684,836	0	X-GW-AM		8.20E+01	0	0	$2,306,000
4	Vinyl Chloride	75-01-4	A	A	8.60E-01	8.95E+05	15	0.20	2,684,836	2.30E+03	VOC	2.00E-03				
				B												
				C												
				D											V-GW-AY	V-GW-ACT
								TOTAL	2,684,836	2.30E+03	V-GW-AM		7.05E+00	327	27	$5,447,233
5	Lead			A	1.56E+00	8.95E+05	15	0.20	2,684,836	4.15E+03	Metal	1.50E-02				
				B												
				C												
				D											L-GW-AY	L-GW-ACT
								TOTAL	2,684,836	4.15E+03	L-GW-AM		1.28E+01	324	27	$5,424,279
6				A												
				B												
				C												
				D												
								TOTAL								
7				A												
				B												
				C												
				D												
								TOTAL								
8				A												
				B												
				C												
				D												
								TOTAL								

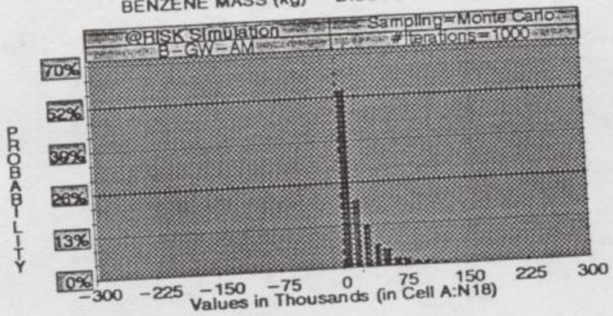

Comparison of Input Distribution and Lognormal(1.80,2.99)
Ethyl Benzene Dissolved Phase Conc (mg/l)
1.3
0.6
0.0
0.00
1.08
2.16
3.24
4.32
5.40
Input
Lognormal

ENVIRONMENTAL STRATEGIC MANAGEMENT PLAN – WORKSHEETS

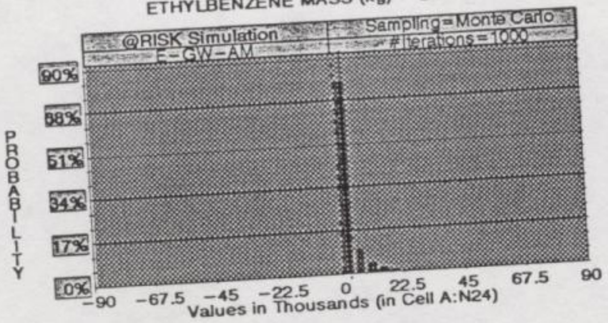
DISSOLVED PHASE
ESTIMATED CONTAMINANT MASS

CLIENT:
PROJECT:
EMCON INDUSTRIAL ENVIRONMENTAL SYSTEMS – HOUSTON

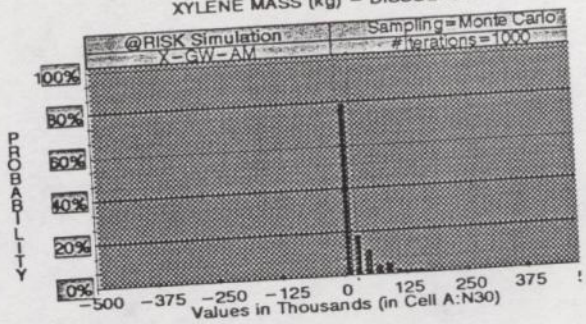
BENZENE MASS (kg) – DISSOLVED PHASE



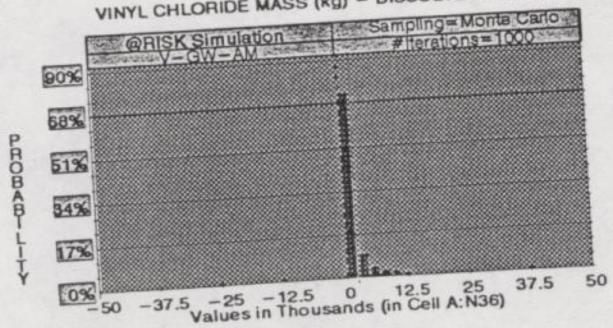
ETHYLBENZENE MASS (kg) – DISSOLVED PHASE



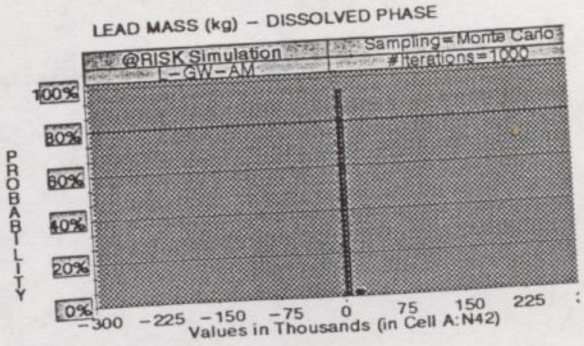
XYLENE MASS (kg) – DISSOLVED PHASE



VINYL CHLORIDE MASS (kg) – DISSOLVED PHASE



LEAD MASS (kg) – DISSOLVED PHASE

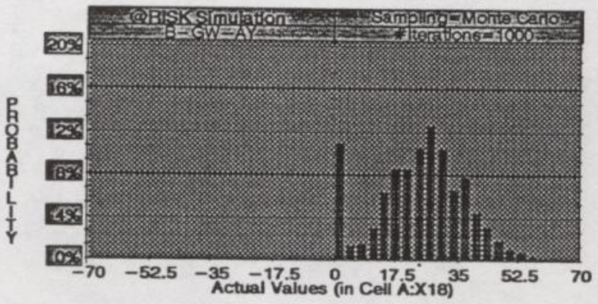


ENVIRONMENTAL STRATEGIC MANAGEMENT PLAN – WORKSHEETS

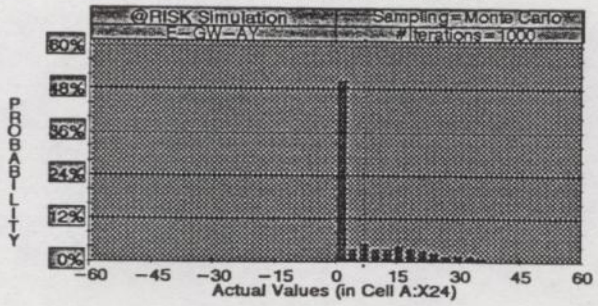
CLIENT:
PROJECT:
EMCON INDUSTRIAL ENVIRONMENTAL SYSTEMS – HOUSTON

DISSOLVED PHASE
ESTIMATED CONTAMINANT MASS REMEDIATION DURATION

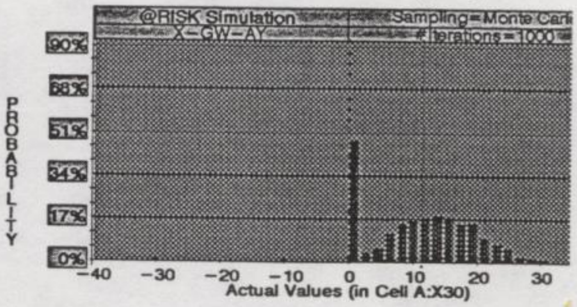
ESTIMATED BENZENE DISSOLVED PHASE
REMEDIATION DURATION (Years)



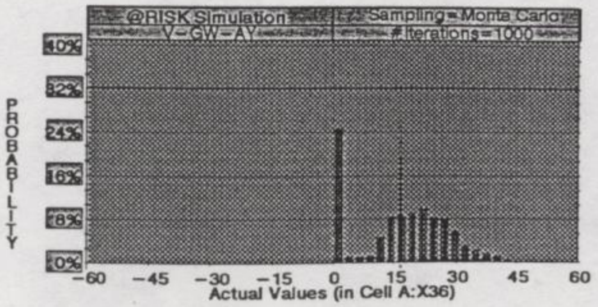
ESTIMATED ETHYLBENZENE DISSOLVED PHASE
REMEDIATION DURATION (Years)



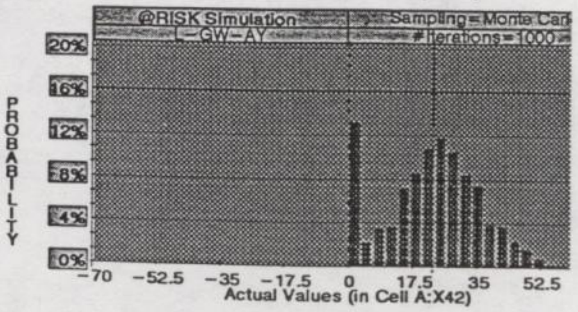
ESTIMATED XYLENE DISSOLVED PHASE
REMEDIATION DURATION (Years)



ESTIMATED VINYL CHLORIDE DISSOLVED PHASE
REMEDIATION DURATION (Years)



ESTIMATED LEAD DISSOLVED PHASE
REMEDIATION DURATION (Years)



ENVIRONMENTAL STRATEGIC MANAGEMENT PLAN – WORKSHEETS

CLIENT:
PROJECT:
EMCON INDUSTRIAL ENVIRONMENTAL SYSTEMS – HOUSTON

ESTIMATED DISSOLVED PHASE REMEDIATION COSTS