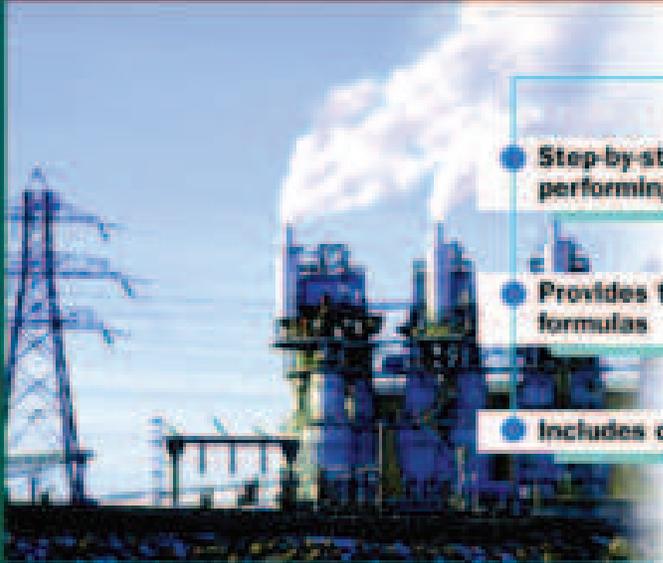


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ENVIRONMENTAL RISK ANALYSIS

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*To my parents,
to Katrina and Demi,
and mostly to my wife, Cleo*

Evan K. Paleologos

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CONTENTS

Preface xiii

Chapter 1. Introduction to Environmental Problems: Transport, Burial, Monitoring, Spillage, Leakage, and Cleanup **1**

- 1.1. Transport Problems / 6
- 1.2. Burial/Storage Problems / 6
- 1.3. Monitoring Problems / 7
- 1.4. Spillage Problems / 8
- 1.5. Leakage Problems / 8
- 1.6. Summary / 9

Chapter 2. Contracts and Decisions **11**

- 2.1. General Development / 11
- 2.2. Parameter Uncertainties / 13
- 2.3. Numerical Example / 16
- 2.4. Discussion / 17
- Appendix 2A: Some Properties of a Log-Normal Distribution / 18
 - 2A.1. Exact Statements / 18
 - 2A.2. Approximate Statements / 20
 - 2A.3. Multiple-Parameter Distributions / 21

Chapter 3. Transport and Burial Hazards of Radioactive Waste **23**

- 3.1. Introduction / 23
- 3.2. Risk and Catastrophe in the Transport of Radioactive Waste / 24
- 3.3. Statistical Measures / 25
- 3.4. Analysis of Alternate Actions: Limited Spill / 28
- 3.5. Analysis of Alternate Actions: Catastrophic Spill / 31
- 3.6. Parameter Uncertainty Effects / 33
 - 3.6.1. Means and Variances / 34
 - 3.6.2. Relative Importance / 35
- 3.7. Relative Contribution of Uncertain Parameters in Subsurface Hydrology / 36
 - 3.7.1. Introduction / 37
 - 3.7.2. Physical Problem / 37
 - 3.7.3. Theoretical Framework / 40
 - 3.7.4. Results and Discussion / 42
- 3.8. Summary / 43
- Appendix 3A: Approximations for Cumulative Probability / 45

Chapter 4. Utility Theory and Working-Interest Optimization in a Hazardous Waste Transport and Burial Opportunity **47**

- 4.1. Introduction / 47
- 4.2. Working-Interest Evaluation / 48
 - 4.2.1. Exponential Utility Function / 50
 - 4.2.2. Parabolic Utility Function / 53
- 4.3. Applications / 54
- 4.4. Summary / 59
- Appendix 4A: Limiting Expressions for Certainty Equivalent / 59
- Appendix 4B: Parabolic Approximation to Exponential Utility / 62

Chapter 5. Catastrophic Events, Insurance, and Unilateral Regulatory Changes **65**

- 5.1. Introduction / 65
- 5.2. Catastrophic Loss in Exploration Assessments / 67
- 5.3. Catastrophic Loss after Oil Is Found / 71
- 5.4. Insurance for Hydrocarbon Exploration and Development Risks / 73
- 5.5. General Catastrophic Loss Conditions / 74
 - 5.5.1. Mathematical Considerations / 74
 - 5.5.2. Numerical Illustration / 78
- 5.6. Insurance Coverage After Oil is Found / 79
 - 5.6.1. General Considerations / 79
 - 5.6.2. Numerical Illustration / 81
- 5.7. Insurance against Catastrophic Loss for Environmental Projects / 82
- 5.8. Optioning against Potential Regulatory Changes / 85
- 5.9. Risk Retention / 86
 - 5.9.1. Evaluation of Risk Reserve Fund / 88
 - 5.9.2. Projects Awarded at One Time Exposed to Liability L / 88
 - 5.9.3. Projects Awarded at Different Times Exposed to Liability L / 90
 - 5.9.4. Projects of Variable Magnitude Awarded at Different Times and Exposed to Liability L / 93
 - 5.9.5. Numerical Illustrations / 95
- 5.10. Summary / 97

Chapter 6. Limiting Risk Using Fractional Working Interest **99**

- 6.1. Introduction / 99
- 6.2. General Methods / 100
 - 6.2.1. Cozzolino's Formula / 101
 - 6.2.2. Hyperbolic Risk Aversion / 104
- 6.3. Numerical Illustration / 105
 - 6.3.1. Results from Cozzolino's Formula / 106
 - 6.3.2. Results from the Hyperbolic Formula / 110
 - 6.3.3. Comparison of Results / 110
- 6.4. Negative Expected Value / 113
- 6.5. Summary / 114

Chapter 7. Limiting Risk Within a Consortium and Foreign Government Projects **117**

- 7.1. Introduction / 117

- 7.2. RAV Estimates with Uncertainties / 118
 - 7.2.1. General Considerations / 118
 - 7.2.2. Numerical Illustrations / 119
- 7.3. Evaluation of Participation in a Consortium of Companies / 128
- 7.4. Evaluation of Participation in Foreign Government Projects / 132
- 7.5. Summary / 136

Chapter 8. Corporate Involvement in Multiple Environmental Projects 139

- 8.1. Introduction / 139
- 8.2. Deterministic Portfolio Balancing / 140
 - 8.2.1. Relative Importance / 140
 - 8.2.2. Profitability / 140
 - 8.2.3. Costs / 141
- 8.3. Budget Constraints / 142
 - 8.3.1. High Budget / 142
 - 8.3.2. Low Budget / 142
- 8.4. Finding the Best Working Interests / 142
 - 8.4.1. The Parabolic RAV Formula / 144
 - 8.4.2. The Exponential RAV Formula / 146
- 8.5. Deterministic Numerical Illustrations / 148
 - 8.5.1. A Budget of \$20 Million / 149
 - 8.5.2. A Budget of \$11 Million / 149
 - 8.5.3. A Budget of \$4 Million / 150
- 8.6. Probabilistic Portfolio Balancing / 150
- 8.7. Probabilistic Numerical Illustrations / 151
 - 8.7.1. Variable Value / 151
 - 8.7.2. Variable Value and Cost / 154
 - 8.7.3. Variable Value, Cost, and Success Probability / 155
 - 8.7.4. Very Low Budget / 155
 - 8.7.5. Low to High Budget Comparison / 157
- 8.8. Comparison of Parabolic and Exponential RAV / 161
 - 8.8.1. Deterministic Results / 161
 - 8.8.2. Statistical Results / 162
- 8.9. Transport and Burial of Wastes / 164
- 8.10. Multiple Projects / 169
- 8.11. Exposure and Expenditure Constraints / 171
 - 8.11.1. Corporate Exposure / 171
 - 8.11.2. Cost Expenditure / 172
- 8.12. Optimal Working Interest / 172
- 8.13. Parabolic Utility Function / 175
- 8.14. Application / 171
- 8.15. Summary / 178
- Appendix 8A: Weighted RAV Optimization / 180

Chapter 9. Apportionment of Cost Overruns to Hazardous Waste Projects

183

- 9.1. Introduction / 183
- 9.2. Project Costs and Cost Overruns / 184
- 9.3. Numerical Illustrations / 186
 - 9.3.1. Identical Projects / 186
 - 9.3.2. Unequal Projects / 187
- 9.4. Arbitrary Numbers of Projects / 188
- 9.5. Summary / 190

Chapter 10. Bayesian Updating of Toxic Leakage Scenarios **193**

- 10.1. Introduction / 193
- 10.2. Theoretical Considerations / 193
- 10.3. General Concepts of Bayesian Updating / 194
- 10.4. Numerical Illustration / 196
 - 10.4.1. Updating the Likelihood of a State Being Correct / 196
 - 10.4.2. Updating the Probability of Leakage / 197
- 10.5. Bayesian Decision Criteria / 199
 - 10.5.1. Optimal Expected Value Bayes Decision / 199
 - 10.5.2. Expected Opportunity Loss / 203
 - 10.5.3. Influence of the Length of the Observation Record on Decision Making / 205
 - 10.5.4. Influence of the Form of the Loss Function on Decision Making / 206
- 10.6. Summary / 210

Chapter 11. Multiple Transport of Hazardous Material: Probabilities of Profitability **211**

- 11.1. Introduction / 211
- 11.2. Statistical Measures for Individual Transport Trips / 211
 - 11.2.1. Statistics for a Single Event / 212
 - 11.2.2. Statistics for Multiple Events / 214
 - 11.2.3. Bayesian Updating of Probabilities / 215
 - 11.2.4. Residual Trips and Probability Updating / 217
- 11.3. Budget Buyout Considerations / 217
- 11.4. Numerical Illustrations / 218
 - 11.4.1. Multiple Transport before a Catastrophe Occurs / 218
 - 11.4.2. Ship Disaster and Probability Updating / 219
 - 11.4.3. Buyout Price and Minimum Acceptable Chance / 219
- 11.5. Summary / 220

Chapter 12. Maximizing Profit for a Toxic Waste Site Monitoring System **223**

- 12.1. Introduction / 223
- 12.2. Scientific Considerations / 224
- 12.3. Financial Considerations / 225
- 12.4. Numerical Illustration / 228
- 12.5. Summary / 229

Chapter 13. Option Payments for Future Information **231**

- 13.1. Introduction / 231
- 13.2. Maximum Option Payments / 232
 - 13.2.1. Mean Value Assessment of Option Costs / 234
 - 13.2.2. Probabilistic Assessment of Option Costs / 235
- 13.3. Numerical Illustrations / 236
 - 13.3.1. Mean Value Assessment of Option Costs / 237
 - 13.3.2. Probabilistic Assessment of Option Costs / 237
- 13.4. Summary / 238

**Chapter 14. The Worth of Resolving Uncertainty
for Environmental Projects** **241**

- 14.1. Introduction / 241
- 14.2. Representation of Risk and Uncertainty / 244
- 14.3. Application to the Question: Is Value Added? / 247
- 14.4. Summary / 249

**Chapter 15. Scientific Uncertainty in Environmental Problems:
Models and Data** **251**

- 15.1. Introduction / 252
- 15.2. Continuous Measurements of Hydraulic Head / 253
 - 15.2.1. Weighting Factors / 253
 - 15.2.2. Parameter Determination / 255
 - 15.2.3. Illustrative Example / 255
 - 15.2.4. Spatial Changes and Partitions / 260
- 15.3. Discrete Measurements of Hydraulic Head / 261
- 15.4. Stochastic Determinations / 262
 - 15.4.1. General Considerations / 262
 - 15.4.2. Parameter Determination / 263
 - 15.4.3. Weighting Factors / 265
 - 15.4.4. Numerical Illustration / 266
- 15.5. Averaging Measures for Hydrodynamic Problems / 268
 - 15.5.1. Specific Hydrodynamic Flow Model / 269
 - 15.5.2. Discussion / 274
- 15.6. Summary / 275
- Appendix 15A: General Development of Procedures for N Models / 276
 - 15A.1. Continuous, Perfect Measurements / 276
 - 15A.2. Discrete, Perfect Data / 277
 - 15A.3. Stochastic Measurements / 278
- Appendix 15B: Individual Parameter Determination Procedure / 281
- Appendix 15C: Measures of Model and Observational Mismatch / 283

**Chapter 16. Human, Water, Chemical, Biological and
Radioactive Risks** **287**

- 16.1. Introduction / 288
- 16.2. Natural Environmental Problems / 288
- 16.3. Anthropogenic Environmental Problems / 289
 - 16.3.1. Examples of Anthropogenic Environmental Problems / 290
 - 16.3.2. Resources and Environmental Issues / 297
- 16.4. Remediation of Environmental Problems / 300
- 16.5. Rules for Addressing Environmental Problems / 301

Chapter 17. Epilogue **303**

Appendix 1. Phase I, II, and III Site Assessments **305**

Appendix 2. Brief Overview of the Federal Statutes of the United States 379

References 423

Index 431

PREFACE

The disposition of chemical, biologic, radioactive, and toxic wastes is perhaps one of the quintessential environmental problems of the past century and the foreseeable future. From the technical and scientific points of view, the major concerns have to do with transport, burial, and monitoring. The aims are to transport the waste without spillage due to mishap (natural or human error), to bury the waste in such a way that there is no leakage thereafter, and to monitor the burial site in a continuous fashion for any leakage after burial. While these aims are the zenith, the nadir is spillage during transport, burial with catastrophic leakage, and a monitoring system that fails.

Scientific analyses of environmental projects are hindered by significant uncertainties. Characterization of present-day conditions at environmental sites is almost always limited because of financial constraints and because the complex interaction of physical, chemical, and biologic processes that control the transport of contaminants is usually not well understood. This situation is accentuated by the requirement that a repository site needs to provide efficient isolation of the waste from the environment and human population over long periods of time and, correspondingly, of the liability claims that an environmental company may have to face long after completion of a project. Future geologic events (e.g., earthquakes, floods, climate change, etc.), all of which can influence the ability to control and isolate the waste over time, introduce further uncertainties. Moreover, the existing technological solutions are limited in their efficiency and expensive to implement and can generate by-products that are difficult to control. The situation increases in complexity with litigation issues, where a significant expense can develop such that funds that otherwise could have been allocated for development and application of new technologies are used up in attempts to resolve legal issues.

Over the past two decades, an enormous effort has been expended (in particular for potential nuclear waste depositories) to account for the uncertainty in site conditions, and this has led to a shift in the focus of scientific studies at academic institutions, national laboratories, and most major environmental companies from the analysis of perfectly determined systems to systems that are described statistically. Combined with the lack of efficient technological developments, this has led regulatory federal and state agencies increasingly to recognize risk as an integral part of environmental projects and to require scientific and financial risk analyses.

There is another side to the problem of waste disposal, however. Eventually, a corporation (or corporations) will have to have transport, bury, and monitor the waste,

usually under a contract from a regulatory agency. The contract usually will contain performance criteria to be met but also will contain a price to be paid to the contractor. The question of interest to the corporation is whether the contract is profitable and under what conditions. There is clearly some sort of financial limit depending on the prior estimates of probabilities of transport (with or without spillage), burial (with or without leakage), and ongoing monitoring costs. Additionally, regulatory agencies, concerned citizen groups, and political staff attached to a lawmaker may all wish to become involved in the various components affecting the decision making at various stages. From the corporate perspective, the problem is to ascertain what associated costs make it worthwhile to accept the contract. From an environmental corporation's perspective, scientific uncertainties and limitations of the technological solutions are only a subset of the total uncertainties it faces. Changing political, financial, and regulatory conditions constitute other unpredictable components in a project's performance and financial return.

The purpose of this book is to explore from a corporate perspective how the preceding issues can be addressed when environmental projects are assessed. In light of these considerations, one may distinguish two main objectives of this monograph. The first is to provide a coherent and unified account of the most critical components entering risk analyses of environmental projects. Thus the influence of various risk factors (arising from scientific uncertainties, technological limitations, regulatory changes, and unpredictable events) on a project's performance is fully illuminated and incorporated into the risk-analysis framework. Additionally, this book aims to incorporate in the decision analyses of environmental projects some recent techniques, which, though not usually discussed in standard risk-analysis books, have become essential in the application of effective corporate environmental strategies. Topics such as innovative types of insurance coverage, partial involvement in multiple projects, corporate alternatives to changes in regulations and/or catastrophic events have seen wide application in other business operations but still have to be included in a comprehensive way in risk analyses of the environmental industry. This book aims to bring exposure to such topics and to include these alternatives as an integral part of environmental risk analyses. The second objective of the book is to provide a step-by-step approach to planning and performing an effective environmental risk assessment. The individual chapters are organized in such a way that an environmental decision-making group can, by starting from the preliminary stage of financial analysis of a project, proceed to address more complex situations and financial alternatives in a systematic manner. Thus the summaries that are provided at the end of individual chapters can operate as a checklist of an environmental project's risk-assessment progress and help in evaluating whether all available alternatives have been explored.

This book is organized as follows: Chapter 1 provides an exposition of some common risks encountered in the transport, burial and storage, and monitoring phases of waste. Chapter 2 sets the stage for a preliminary risk analysis of environmental projects by considering the simplest situation of a contract offered under

fixed regulations, with no catastrophic loss events, without inclusion of either optional insurance or of corporate risk tolerance, and without the occurrence of spillage or leakage. Chapter 3 introduces three statistical measures that can be used in risk analyses of environmental projects that face the possibility of limited or catastrophic losses. Particular emphasis in this chapter is placed on the inclusion of catastrophic scenarios in risk analyses because these can alter substantially the perspective on a project and lead environmental corporations away from investments. Chapter 4 introduces the concept of corporate risk tolerance and presents a methodology that addresses risk considerations through partial project involvement. Chapter 5 develops the framework for the inclusion of insurance alternatives in environmental risk analyses and presents a procedure that allows small environmental companies to address limited-liability claims for a number of situations. Chapters 6 and 7 expand the concept of risk-adjusted value to more complex cases of environmental risk and provide procedures that can be used to determine the dominant uncertainty factors that influence a project's return and performance. Chapter 8 presents a methodology for optimizing total corporate return for a portfolio of opportunities in the face of a constrained budget, and Chapter 9 deals with the apportionment of cost overruns to various environmental projects in such a way as to maximize total corporate return. Chapters 10 and 11 provide the framework for bayesian updating of leakage scenarios and multiple transport of hazardous material, respectively. Chapters 12, 13, and 14 address issues of regulatory compliance and project monitoring strategy, the use of option payment as an alternative to insurance coverage, and the worth of collecting additional data. Chapter 15 discusses some problems of scientific uncertainty in the representation of a hydrologic system that are due to model selection and resolution of data, while Chaps. 16 and 17 provide concluding remarks on the interrelation of human, scientific, and financial considerations for environmental projects. Finally, the two appendixes provide a summary of the regulations that govern Phase I, II, and III site assessments, and also give a brief overview of the federal statutes that are applicable to environmental problems.

The monograph is set at a level where an environmental, civil, or chemical engineer or scientist involved in environmental problems should have little difficulty not only in following the arguments presented but also in actively building on the precepts expounded here to a higher level than we present. For corporate executives, it is hoped that the work presented here will remove some of the less than objective assessments of economic worth of an environmental project that occasionally have been the lot in the past. Although this is an application-oriented book, the material is set at a graduate study level so that it can be used as a textbook in courses of decision analysis offered at engineering or science departments. Toward this objective, the book not only provides an exposition and application of decision-analysis theory to practical environmental problems but also includes topics not usually covered in standard risk-analysis textbooks that are critical in comprehensive risk assessments of environmental projects and the analysis of corporate alternatives.

We are grateful to a large body of people for their input, advice, and criticisms of the ideas developed here. And we are keenly aware that this monograph does not do justice to all economic aspects of all environmental problems. Such a development would make for a very long tome indeed and one that is well beyond our abilities. However, we will have succeeded in our endeavor if others, more able than ourselves, can bring the tools and methods presented here to as sharp a focus as possible over the years. More appropriate statements of economic evaluation can then be made which can help to guide the future toward the most important technical and scientific developments needed to integrate scientific risk and uncertainty with economic risk and uncertainty. It is with these goals in mind that the present monograph has been written.

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