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GOLF COURSE MANAGEMENT:

ENVIRONMENTAL ISSUES

*A Final Report to the United States Golf Association: Green
Section on the Manuscript Submitted to Lewis Publishers Inc.*

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1.0 Scope and Objectives of the Project

A report on the environmental effects of golf course and turfgrass management was originally developed by Spectrum Research, Inc. for the United States Golf Association: Green Section (USGA). With growing public concern over environmental, water use, water quality, and health related issues, the USGA recognized the need for accurate and unbiased information on the potential effects of certain turfgrass management practices. With their active commitment to resource conservation and mitigation of potential adverse environmental effects of turfgrass systems, both the USGA and Spectrum Research, Inc. recognized the need to disseminate this report to turfgrass managers, other scientists, and the public. To meet this objective Spectrum Research, Inc. substantially revised and improved the original report for publication by Lewis Publishers, Inc.

The final manuscript for the book titled "Golf Course Management: Environmental Issues", was submitted to Lewis Publishers, Inc. on October 4, 1991. The manuscript significantly updates and augments the original report. The book is a summary and assessment of the technical and scientific research on the environmental effects of turfgrass management and to a smaller extent golf course construction. This book is intended as an introduction to the concepts of the nonpoint source environmental impacts of turfgrass management for turfgrass scientists and specialists, landscape and golf course architects, developers of turfgrass systems and golf courses, golf course superintendents, environmental scientists, and land use regulators.

The manuscript is organized into eight chapters. The introduction provides an overview and historical perspective regarding turfgrass management and environmental quality. The second chapter discusses the relationship of turfgrass management to the critical issues of water resources. This chapter focuses on the issues of water use, water quality, soil and water conservation, and movement within the water cycle. Chapters three and four provide a state-of-the-art scientific review and assessment of the literature regarding the environmental effects of nutrient and pest management practices. The fifth chapter provides an introduction to concepts necessary for development of integrated management systems for turfgrass. Chapter six covers the direct and indirect effects of golf course management and construction on wildlife and aquatic organisms. The seventh chapter is an introduction to the critical issues of conservation and protection of wetlands which is emerging as a critical environmental concern of the 1990s. Chapter 8 contains tables of toxicity tests related to the effect of chemicals used for turfgrass management. Each of the chapters includes a section on research and information needed to resolve the issues surrounding the positive and potentially adverse effects of

turfgrass management. An outline of the manuscript is provided in Section 2.0.

Many individuals made significant contributions in preparing this publication. The contributors and reviewers included staff members of Spectrum Research, Inc., the staff of the USGA; members of the USGA research committee; scientists from Environmental Chemistry and Lockheed Engineering & Sciences Company; and academic scientists (Table 1). All of the contributors were cooperative and made timely contributions to the quality of the publication. Several authors and reviewers were pivotal in enhancing the quality of the book. Spectrum Research, Inc. specifically acknowledges the outstanding efforts by Michael P. Kenna, James R. Watson, Victor A. Gibeault, James T. Snow, and Anne R. Leslie in making this publication possible. In addition to authorship, their reviews and professional guidance were greatly appreciated by the editors and co-authors.

Ultimately, the objective of this project is to objectively distribute information regarding the environmental effects of golf course management. This will be an ongoing process for the USGA environmental research program. The staff of Spectrum Research, Inc. believes the book, *Golf Course Management: Environmental Issues*, will make a positive contribution to the long term goals of the research efforts of the USGA.

Table 1. List of Contributors.

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2.0 Outline of the Publication

Chapter 1 BACKGROUND AND OVERVIEW OF ENVIRONMENTAL ISSUES

James C. Balogh, Victor A. Gibeault, William J. Walker,
Michael P. Kenna, and James T. Snow

- 1.1 Introduction
- 1.2 Environmental Issues and Turfgrass Management:
A Historical Perspective
- 1.3 Scope of the Turfgrass Industry
- 1.4 Environmental Benefits of Turfgrass Systems
- 1.5 Identification of Environmental Impacts and
Nonpoint Pollution Problems in Turfgrass Systems
- 1.6 Benefits of Implementing Integrated Turfgrass Management
Strategies
- 1.7 Objectives and Sources of Information

Chapter 2 ROLE AND CONSERVATION OF WATER RESOURCES

James C. Balogh and James R. Watson

- 2.1 Introduction: Water Resources and Turfgrass
- 2.2 Components of the Water Cycle, Soil, and Turfgrass Systems
- 2.3 Transport Processes
 - 2.3.1 Surface Water
 - 2.3.2 Groundwater
 - 2.3.3 Water and Chemical Movement in the Unsaturated Zone
 - 2.3.4 Soil Properties Affecting Movement of Turfgrass Chemicals
 - 2.3.5 Additional Concerns for Susceptibility of Groundwater to Contamination
 - Includes section on leaking underground storage tanks.
- 2.4 Soil and Water Conservation in Turfgrass Management
 - 2.4.1 Sediment and Runoff Control with Turfgrass
 - 2.4.1.1 Processes and Control for Established Turfgrass
 - 2.4.1.2 Runoff and Sediment Control During Site Construction and Turfgrass Establishment
 - 2.4.1.3 Design Considerations to Reduce Runoff and Erosion
 - 2.4.2 Turfgrass and Water Conservation
 - 2.4.2.1 Water Stress and Mechanisms to Resist Drought
 - 2.4.2.2 Water Use and Drought Resistance
 - 2.4.2.3 Water Conservation and Cultural Practices: Mowing, Fertilization, and Irrigation
- 2.5 Research Needs

Chapter 3 ENVIRONMENTAL IMPACTS OF TURFGRASS FERTILIZATION

William J. Walker and Bruce Branham

- 3.1 Use of Turfgrass Fertilizers and Environmental Impacts
 - 3.1.1 Use of Fertilizers in Golf Course Construction and Maintenance
 - 3.1.2 Environmental Issues Related to Fertilizer Use in Turfgrass Systems
 - 3.1.3 Health Issues of Inorganic Fertilizers and Nitrate in Drinking Water

- 3.1.4. Environmental Effects of Inorganic Fertilizers
- 3.2 Nitrogen Cycle and Chemical Properties
- 3.3 The Phosphorus Cycle and Chemical Properties
- 3.4 Nutrient Losses from Cultivated Systems
 - 3.4.1 Nutrient Loss from Surface Runoff
 - 3.4.2. Nutrient Loss from Subsurface Transport
- 3.5 Nutrient Losses from Turfgrass Systems
 - 3.5.1 Nitrogen Loss Through Volatilization
 - 3.5.2 Nitrogen Loss Through Subsurface Drainage
 - 3.5.3 Nutrient Loss through Surface Runoff
- 3.6 Nutrient Loss from Turfgrass and Management Guidelines

Chapter 4 ENVIRONMENTAL IMPACTS OF TURFGRASS PESTICIDES

James C. Balogh and James L. Anderson

- 4.1 Introduction
- 4.2 Uses of Pesticides in Turfgrass Management
- 4.3 Development of Insect Resistance
- 4.4 Pesticides, Environment, and Health Issues
- 4.5 Fate and Persistence of Pesticides in Turfgrass
 - 4.5.1 Initial Distribution
 - 4.5.2 Drift and Volatilization
 - 4.5.3 Adsorption and Retention
 - 4.5.4 Decomposition and Persistence
- 4.6 Pesticides and Water Quality
 - 4.6.1 Runoff and Surface Water Quality
 - 4.6.2 Subsurface Movement of Pesticides
 - Mass Transport of Pesticides
 - Case Studies of Pesticide Leaching from Turfgrass
- 4.7 Management Guidelines Related to Pesticides and Water Quality
- 4.8 Research and Technology Transfer Needs

**Chapter 5 Development of Integrated Management Systems
for Turfgrass**

James C. Balogh, Anne R. Leslie,
William J. Walker, and Michael P. Kenna

- 5.1 Concept of Integrated Management Systems for Turfgrass
- 5.2 Components of Integrated Management Systems for Turfgrass
 - 5.2.1 System Components
 - 5.2.2 Management Guidelines in TMS
- 5.3 Adoption of Integrated Systems for Turfgrass Management
- 5.4 Alternate Methods of Pest and Disease Control
- 5.5 Qualitative and Quantitative Techniques to Assess Environmental Impacts
- 5.6 Conclusions

Chapter 6 WILDLIFE AND GOLF COURSES

Roberta M. Tietge

- 6.1 Introduction: Values and Aesthetics of Wildlife
 - 6.1.1 Wildlife Values
 - 6.1.2 Golf Course Aesthetics and Wildlife
- 6.2 Impacts of Turfgrass Pesticides on Wildlife
 - 6.2.1 What is the Toxicity of Pesticides to Wildlife?
An Overview of the Regulatory Perspective
 - 6.2.2 Direct Effects: Acute and Chronic Toxicity
 - 6.2.2.1 Definitions of Toxicity Tests and Effects
 - 6.2.2.2 Impacts of Turfgrass Pesticides on Wildlife:
A Risk Assessment
- 6.3 Golf Courses as Wildlife Habitat
 - 6.3.1 Wildlife Habitat Selection
 - 6.3.2 Indirect Effects of Pest Management on Wildlife Habitat
 - 6.3.3 Protection of Wildlife Habitat During Golf Course Development

- 6.4 General Guidelines for Wildlife Habitat Enhancement
- 6.5 Conclusion

Chapter 7 WETLANDS AND GOLF COURSES

Patricia A. Kosian, Mary E. Balogh, and Roberta M. Tietge

- 7.1 Introduction
- 7.2 Definitions of Wetlands
- 7.3 Wetland Types and Classification
- 7.4 Extent of Wetlands and Golf Courses
 - 7.4.1 Status and Trends of Wetlands: 1954-1974
 - 7.4.2 Status and Trends: 1979-1991
 - 7.4.3 Estimated Distribution of Golf Courses
- 7.5 Wetland Regulations and Permitting Process
 - 7.5.1 Federal Wetland Regulations
 - 7.5.2 State Wetland Regulations
 - 7.5.3 Summary of the Regulatory Process
- 7.6 Wetland Mitigation
 - 7.6.1 Mitigation Policy of the U.S. Fish and Wildlife Service
 - 7.6.2 Mitigation Policy of the EPA and Corps
 - 7.6.3 Mitigation Strategies
 - 7.6.3.1 Wetland Avoidance
 - 7.6.3.2 Minimize Wetland Impacts
 - 7.6.4 Wetland Compensation
 - 7.6.4.1 Compensatory Mitigation Strategies
 - 7.6.4.2 Types of Compensatory Mitigation
 - Wetland Restoration
 - Wetland Creation
 - Wetland Enhancement
 - Wetland Exchange
 - Wetlands Preservation
 - Suggested Choice of Options
 - 7.6.4.3 Credit for Compensatory Mitigation
 - 7.6.4.4 Ratios for Wetland Restoration
 - 7.6.4.5 Timing of Compensatory Mitigation
 - 7.6.4.6 Location of Compensatory Mitigation:
 - Onsite and Offsite Location
 - Mitigation Banking
 - Selection of Community Type for Mitigation Projects

- 7.6.5 Monitoring Mitigation Projects
- 7.6.6 Conclusions on Mitigation Strategies

7.7 Wetland Values and Functions

- 7.7.1 Wildlife and Fish Habitat
- 7.7.2 Shoreline and Erosion Control
- 7.7.3 Flood Protection
- 7.7.4 Water Quality and Storm Water Management
- 7.7.5 Aquifer Recharge
- 7.7.6 Recreation and Aesthetics
- 7.7.7 Summary of Wetland Values

7.8 Wetlands, Golf Course Development, and Management Practices

- 7.8.1 Wetlands and Golf Course Management Practices
- 7.8.2 Wetlands and Development of New Golf Courses
- 7.8.3 Conservation Easements

7.9 Conclusions and Future Research

Chapter 8 AQUATIC AND TERRESTRIAL TOXICITY TABLES

Sheila R. Murphy

- 8.1 Acute and Chronic Toxicity
- 8.2 Summary of Acute and Chronic Toxicity Tests