TABLE OF CONTENTS

List of Tables xx

List of Figures xxiv

List of Symbols xxii

1. INTRODUCTION 1

1.1. Statement of the problem 1

1.2. Background 2

1.3. Objectives of the project 3

1.4. Approach 4

2. FIELD MONITORING AND LABORATORY EXPERIMENTS 7

2.1. Introduction 7

2.2. Materials and methods - Field monitoring 7

2.2.1. Irrigation waters 9
2.2.2. Irrigation pivots 9
2.2.3. Irrigation water treatments 11
2.2.4. Atmospheric measurements 12
2.2.5. Soil measurements 12
2.2.6. Irrigation water chemical analyses 14
2.2.7. Characterization of soil material 14
2.2.8. Soil analyses 15
2.2.9. Measurement of precipitated gypsum 15
2.2.10. Evaluation of changes in soil salinity distribution on the irrigated areas 16
2.2.11. Runoff amounts and quality 17
2.2.12. Installation of monitoring boreholes 17
2.2.12.1. Siting of the boreholes 17
2.2.12.2. Drilling 17
2.2.12.3. Geology and hydrogeology 19
2.2.12.4. Piezometer installation 19
2.2.12.5. Hydraulic characteristics of the aquifer 19
2.2.13. Crop measurements 21

2.3. Results of field monitoring 21

2.3.1. Characterization of soil material 21
2.3.1.1. Soil classification and texture 22
2.3.1.2. Soil bulk density and porosity 22
2.3.1.3. Water retention characteristics 22

2.3.1.4. Hydraulic conductivity characteristics 26
2.3.1.5. Solute transport characteristics 30
2.3.1.6. Gypsum precipitation characteristics 32
2.3.2. Crops 33
2.3.2.1. Yield 33
2.3.2.2. Plant nutrition 36
2.3.3. Soils 36
2.3.3.1. Chemical properties 36
2.3.3.2. Spatial variability of soil salinity 51
2.3.4. Waters 56
2.3.4.1. Irrigation water quality 56
2.3.4.2. Runoff 58
2.3.4.3. Groundwater 61
2.3.4.3.1. Groundwater quality 61
2.3.4.3.2. Groundwater levels 63

2.4. Glasshouse and laboratory experiments 65

2.4.1. Plant nutrition 65
2.4.2. Herbicide effects 66

3. SOIL WATER BALANCE MODEL 67

3.1. Model description 67

3.2. Model validation 70
3.2.1. Soil water balance and crop growth 70
3.2.2. Soil water redistribution 73
3.2.3. Salt redistribution 79
3.2.4. Gypsum precipitation 85
3.2.5. Comparison between SWB and FAO-SWS 87

4. SCENARIO SIMULATIONS 89

4.1. Introduction 89
4.2. Materials and methods 89
4.2.1. Long-term effects of cropping systems and environmental impact 89
4.2.2. Modelling the decision process with MCDM techniques 90
4.2.3. Economic impact 91
4.2.4. Analysis 91
4.3. Results and discussion 93
4.4. Conclusions 95

5. GROUNDWATER MODELLING 97

5.1. Model description and scenario modelling 97

5.2. Governing equations for modelling pollution transport 98

5.3. Hydraulic variables and constraints 101

5.3.1. Transmissivity and hydraulic conductivity 101
5.3.2. Storativity and effective porosity 101
5.3.3. Regional water table gradient, dispersion and convection 101
5.3.4. Boundaries 102
5.3.5. Sources of water 103
5.3.6. Sinks 103

5.4. Links between the irrigation and the groundwater model 103

5.5. Discussion of modelling results 103

6. CONCLUSIONS AND RECOMMENDATIONS 106

7. REFERENCES 112

8. CAPACITY BUILDING 120

9. TECHNOLOGY TRANSFER 121

APPENDIX A: Tables 125

APPENDIX B: Automated tensiometers 203

APPENDIX C: Methods for characterization of soil material 206

APPENDIX D: Methods of measurement of gypsum precipitated in the soil (Soil Science Laboratory, University of Pretoria) 214

APPENDIX E: Calculation of the gypsum saturation index as a method for detecting gypsum in soils, and a preliminary study of sulphate adsorption in soils irrigated with saline mine water at Kleinkopje Colliery (Dept. of Geology, University of Cape Town) 218

APPENDIX F: Borehole logs 228

APPENDIX G: Results from pumping test analysis 233

APPENDIX H: Solute transport characteristics breakthrough curves 238

APPENDIX I: Chemistry of soils and regolith irrigated with gypsiferous mine water 241

APPENDIX J: Results of chemical analyses of borehole water samples 252

APPENDIX K: Growth and nutrient composition of Triticum aestivum L. as affected by nutritional management under sulphate salinity 263

APPENDIX L: Herbicide effects 271

APPENDIX M:	Theory of the finite-difference water balance and convection/dispersion solute redistribution used in the SWB model	276
APPENDIX N:	*Model validation*	288